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Carlisle Groundwater Protection Study

Metropolitan Area Planning Council
110 Tremont Street
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Technical Assistance Report

Carlise Groundwater Protection Study

December 1986

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ABOUT THIS REPORT

This report was prepared by the staff of the Metropolitan Area Planning Council under the supervision of the Executive Director. The Metropolitan Area Planning Council is the officially designated regional planning agency for 101 cities and towns in the Boston metropolitan area. The Council offers technical assistance to its member communities in the areas of land use, housing, environmental quality, energy, transportation, and economic development.

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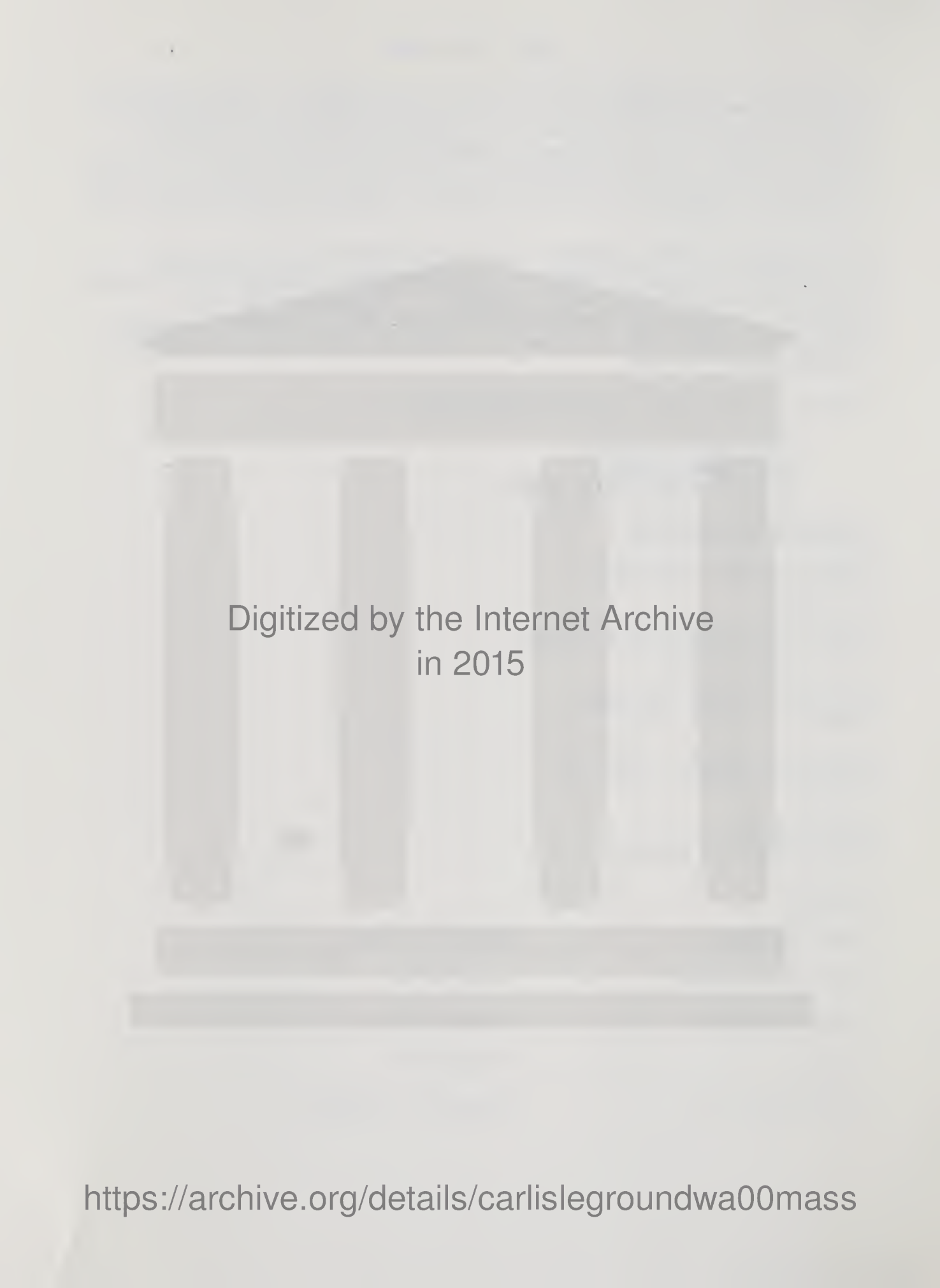
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CHAPTER 1

INTRODUCTORY AND SUMMARY

STUDY PURPOSE AND GOALS

The town of Carlisle has requested MAPC's assistance in evaluating water quality problems associated with groundwater supplies in the town center, and developing recommendations for solving these problems and managing the town's groundwater resources.

This report presents an overview of Carlisle's water resources and water supply situation, an analysis of existing data on water quality problems, a survey of land use and potential sources of contamination, and a recommended set of actions the town can take to improve the management and protection of its groundwater resourcess.

STUDY AREA

The study area for this report is Carlisle center, defined by a 1500 foot radius around the intersection of Rte. 225 and Concord St. (see Figure 2-1), although some of the recommendations of this study may be applied town-wide. The study area is characterized by one-acre lot residential zoning, although many existing lots are less than one acre.

There are also several small businesses in the study area, including a store, a gas station, two banks, and two real estate offices. Also within the study area are the town offices, library, police and fire departments.

SUMMARY OF FINDINGS

All water users in Carlisle rely on private on-lot wells. In recent years, water quality problems have been detected in many town center wells. Wells have been contaminated by sodium, hydrocarbons, and bacteria. This study has evaluated existing water quality and hydrogeologic data, and presents the following findings concerning water quality problems in Carlisle:

(1) Sodium contamination has affected about 30 wells over the last seven years. Although sodium levels appear to be gradually declining, 15 sampled wells still have an average sodium level of 78 milligrams per liter, well above the drinking water standard of 20 mgl. The primary cause of this contamination is a plume of high-sodium groundwater originating at the site of the former open DPW salt storage pile adjacent to the fire department. Although salt has not been stored at this site since 1972, the sodium enriched leachate from the site is now dispersing into the surrounding aquifer and affecting town center wells. The sodium plume will probably continue to migrate through the aquifer for years to come until it is finally attenuated through dispersion and dilution. Without more detailed hydrogeologic study, it is not possible to predict the direction the plume will travel in the fractured bedrock aquifer, or how long it will take to be diluted to lower levels of sodium concentration. However, existing water quality monitoring data show that average sodium levels in 15 wells have dropped by 50 percent (from 150 mgl to 78 mgl) in five years.

Other potential sources of sodium in the study area include application of road salt and septic systems. The study recommends management practices to control these sources.

(2) Hydrocarbons have contaminated at least six wells in Carlisle, requiring one to be abandoned, and treatment to be installed on several others. This contamination was caused by the leaking of an underground gasoline tank at a gas station in Carlisle center in 1978. Widespread impacts were not reported as a result of this single contamination incident. The report includes recommendations for regulation of underground fuel storage tanks.

(3) Bacterial contamination was reported at one well outside the town center in 1983. The pollution was localized and the cause was not determined. While not a widespread problem, there is the potential for bacterial contamination in Carlisle center because of the density of development, the use of both on-lot wells and septic systems, and marginal soil conditions. Proper maintenance of wells and septic systems is important for protection of the water supply. The report offers recommendations for improved septic system and well maintenance.

(4) In addition to existing contamination problems, the town should consider the potential impact of future development on the aquifer. The report suggests land use guidelines which would ensure that future development is compatible with groundwater protection.

SUMMARY OF RECOMMENDATIONS

The recommendations of the study are summarized below:

(1) Groundwater monitoring and further study--the existing sodium contamination should be monitored on at least an annual basis. About 15 town center wells have been sampled periodically since 1978; this provides a very useful database which reveals long term trends in sodium levels. This database should be continued in order to provide the town with data to evaluate the severity of the problem and alternative courses of action in the future. If sodium levels do not decrease to an acceptable level, the town could consider further study of engineering solutions, including an aquifer rehabilitation project, or development of a community water supply system in Carlisle center. However, the costs of such options should be carefully weighed against the benefits.

(2) Road salt application - the Public Works Department should continue to substitute calcium chloride for sodium chloride as a road de-icing chemical in the town center. The DPW should also use the minimum practical amount of calcium chloride for maintaining safe roads. This could be accomplished in part by covering the sand pile, so that less salt would be necessary to keep the sand unfrozen. This will ensure that road salt application does not exacerbate existing sodium contamination, or retard the recovery of the affected aquifer.

(3) Underground fuel storage - existing and new underground fuel storage facilities in Carlisle should be regulated by a town

bylaw or board of health regulation. Provisions should include registration of all underground tanks, inventory control, leak detection measures, standards for new tanks and installation, and spill contingency plans. A model bylaw with these provisions is included in Appendix A.

(4) Septic System Maintenance - the town should encourage proper maintenance of septic systems through a voluntary inspection and maintenance program. The town should continue its public education program, emphasizing the need for periodic pumping of septic tanks, and the hazards of septic system chemical cleaners and improper disposal of toxic or hazardous materials.

(5) Private Well Maintenance - the town should encourage private well owners to properly maintain their wells. MAPC's new publication, the "Private Well Owners Handbook" (produced jointly with Mass. Audubon Society) will be provided to the town. The handbook provides information on sources of contamination, water testing, and water treatment.

(6) Household Hazardous Wastes - proper disposal of household hazardous wastes is vital to groundwater protection, especially in a densely developed non-sewered area like Carlisle center. The town should encourage this through public education. Copies of MAPC's brochure on household hazardous waste will be provided to the town, for distribution to town center residents. The town should also consider organizing a household hazardous waste

collection, such as that sponsored by Lexington and many other Massachusetts communities.

(7) Land Use and Development Guidelines - in order to ensure that future development is compatible with the long-term protection of groundwater resources, the town should adopt land use guidelines which control the type and density of development in Carlisle center, as well as performance requirements regarding runoff and drainage, lot coverge, discharge of pollutants, and storage or disposal of hazardous materials. These guidelines should be implemented in the form of amendments to the zoning bylaw, the subdivision regulations, and site plan review requirements, as follows:

(a) Zoning. The provisions for the General Residence A district should be amended to require lot coverage of no more than 10 percent or 4000 square feet, whichever is greater, including structures and impervious surfaces such as paving. (The Zoning bylaw currently allows 25 percent lot coverage). The use regulations for the Residence A district should also be amended to prohibit uses or activities which involve the use, storage, or disposal of solid or liquid wastes (other than domestic sanitary wastes), hazardous materials, and other accessory uses which involve potentially polluting activities. The Carlisle Center Business District should be amended to require a maximum of 50 percent lot coverage, and the use regulations outlined above for the Residence A district should also apply in this district. Suggested Zoning changes appear in Chapter 6.

Suggested zoning changes appear in Chapter 6.

(b) Subdivision Regulations. It is recommended that the town's subdivision regulations be amended to include an optional requirement for additional information and mitigation measures for groundwater protection, to be required at the discretion of the planning board in cases where the proposed project may affect the quantity or quality of groundwater. These requirements include information on groundwater elevation and groundwater flow, impact on groundwater resources, and evaluation of drainage system alternatives. Suggested subdivision amendments are found in Chapter 6.

(c) Site Plan Review. It is recommended that the site plan review regulations be amended to include consideration of the impacts of development on groundwater resources. Suggested amendments are included in Chapter 6.

These seven recommendations, taken together, form a comprehensive groundwater protection plan for Carlisle center, and offer additional protection town-wide. Implementation of this plan will require the cooperation of the board of selectmen, planning board, board of health, conservation commission, and fire department, as well as public support and town meeting approvals. It is hoped that this report will prove useful in helping the town of Carlisle to implement a sound groundwater protection program.

CHAPTER 2

Water Resources and Water Supply

The town of Carlisle relies entirely on groundwater for its potable water supply. The availablity of groundwater is determined by the hydrology and geology of the aquifer from which it is drawn.

Hydrology. Carlisle center lies within portions of three watersheds - one subbasin of the Assabet River and two subbasins of the Concord River (See Figure 2-1). As such, the study area is a headwater area, and all surface drainage is directed away from the area, either westward to the Assabet River, or to the north and east toward the Concord River. This means that any water quality problems probably originate within the study area-there are no upstream sources which could flow into the area, because the area itself is within the most upstream segment of three watersheds. Further, any quality problems within the study area could affect downstream areas of each of the three watersheds.

Topography. The highest elevation within the study area is 240 feet (msl), which is along School Street near the Wilkins School. Elevations fall off to an average of about 200 feet in the town center, and a low of about 150 feet at the eastern edge of the study area.

Geology. The geology of the study area consists of a hard consolidated bedrock covered by a mantle of glacially-deposited unconsolidated materials. The bedrock is predominantly a metamorphic grey gneiss of the Nashoba formation.

The rock is fine to medium grained and very hard. It has a very low permeability and porosity, thus its stores and transmits very little groundwater. In such a formation, groundwater is found only in fractures in the bedrock. The fractures coincide with the strike and dip of the formation, and occur mostly in the upper 100 to 200 feet of the bedrock. Because the groundwater travels in the channels of the bedrock fracture pattern, there is no filtering action or absorption, and little renovation of pollutants in the groundwater. In fact, the fractures can act as conduits, transmitting pollutants in unpredictable directions and speeds.

The surficial materials overlaying the bedrock are unconsolidated silts, sands, gravels, and tills deposited by the glaciers (see Figure 2-2). Till predominates the study area. This unsorted mixture of materials of all grain sizes, from silt and clay through pebbles and boulders, is impermeable and impervious. Thus it is a poor aquifer, with little ability to store or transmit water. Further, the thickness of the surficial materials is generally less than ten feet, with many areas of bedrock outcrops.

There are also wetlands covering some parts of the study area. These generally consist of one to five feet of organic black muck overlying several feet of till or sand and gravel.

Groundwater. As mentioned above, the geology of the study area is not favorable for groundwater. Due to the low porosity of both bedrock and surficial deposits, there is little groundwater in storage. Due to low permeability, the materials can not transmit water rapidly. Thus, wells in the study area generally yield 3 to 5 gallons per minute, which is adequate for an individual home well, but not for a public water supply.

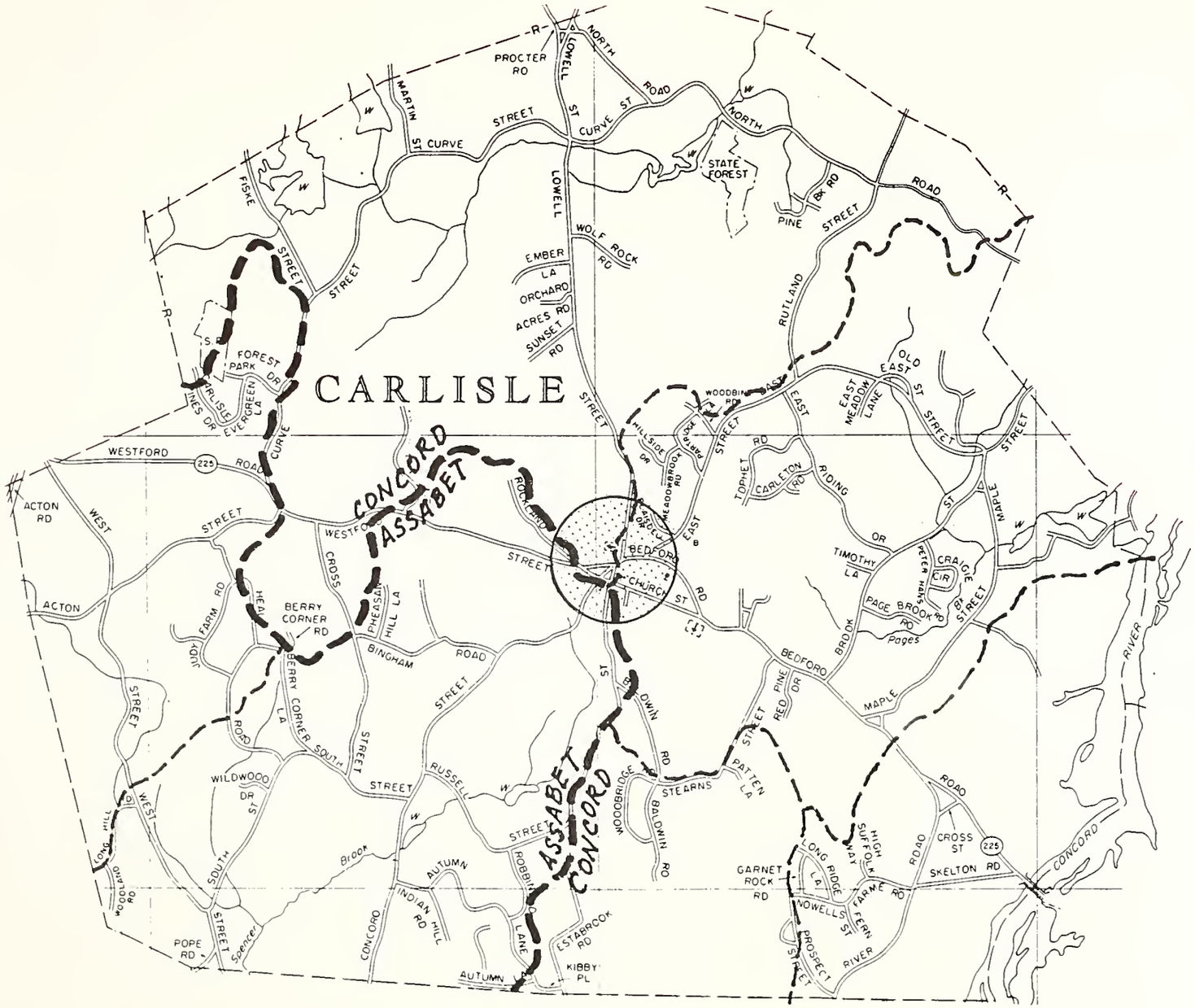
The water table generally follows the contours of the surface topography. The highest gradient is 196 feet; which is at Concord and Westford Streets. Groundwater flow is generally from upgradient areas to discharge areas down-gradient, although groundwater flowing in underlying bedrock fractures may appear to flow in other directions. The water table is less than ten feet below the ground surface in most areas, and at the surface in wetland areas.

Recharge of the groundwater is limited by the low permeability of the area's till deposits. Only about 20 to 30 percent of all precipitation recharges the groundwater, while 70 to 80 percent takes the form of runoff or evaporation.

Water Supply. The town of Carlisle relies entirely on private wells for its potable water supply. The majority of these are drilled wells which draw groundwater from a deep bedrock aquifer; a few shallow dug wells pump from the "water table aquifer" in glacially deposited surficial materials. In the study area, there are approximately 42 wells. Thirty-eight of these are drilled into bedrock at depths of 38 to 400 feet (See Figure 2-3). Four dug wells range from 9 to 15 feet in depth. The town has no central water supply system; all residences and businesses are self-supplied with their own on-lot wells. Water quality problems experienced by these wells are evaluated in the following chapter.

Figure 2-1

WATERSHED BOUNDARIES



BASIN BOUNDARY-
CONCORD/ASSABET

SUB-BASIN
BOUNDARIES

STUDY AREA

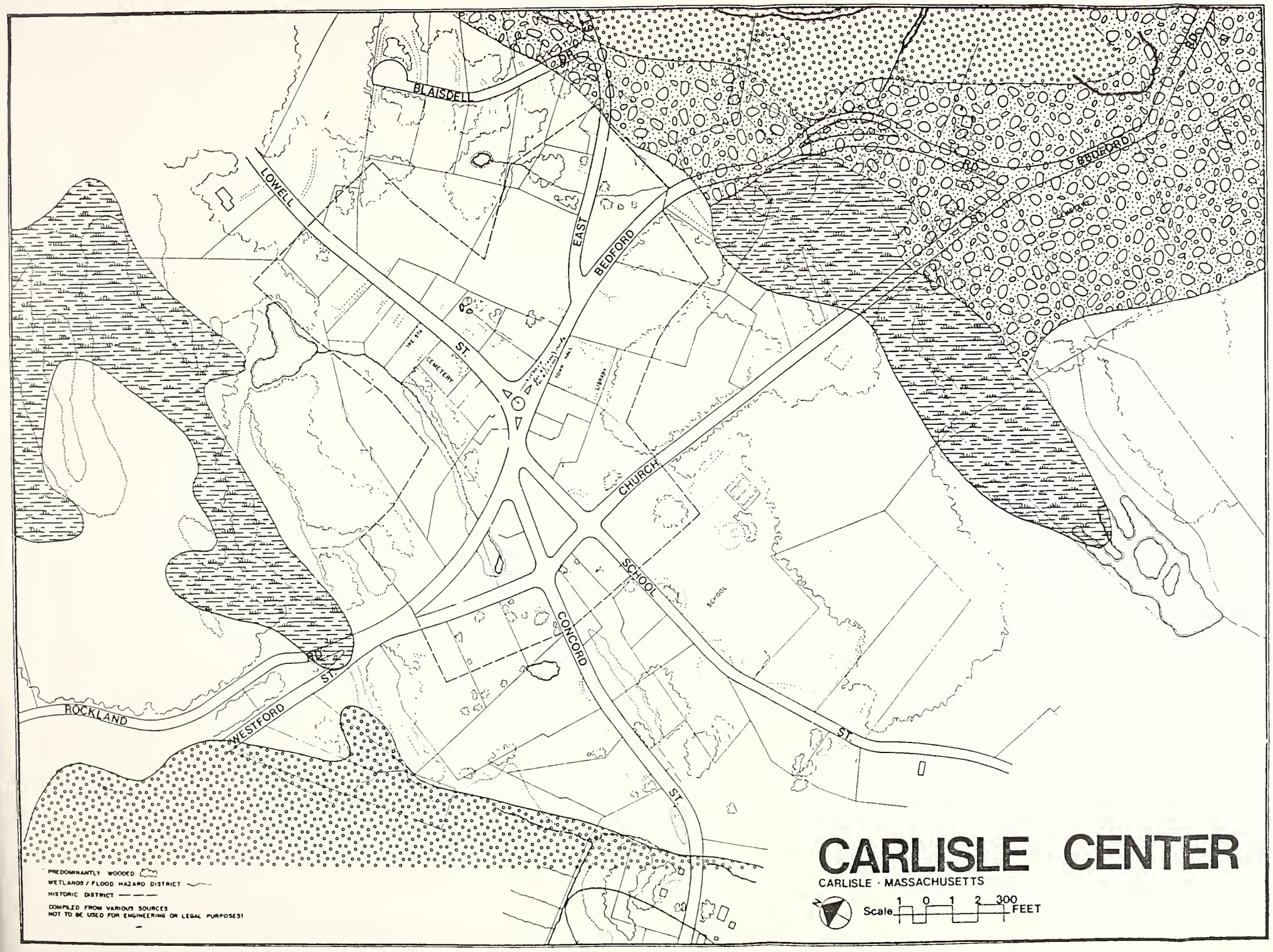


Figure 2-2

Surficial Geology

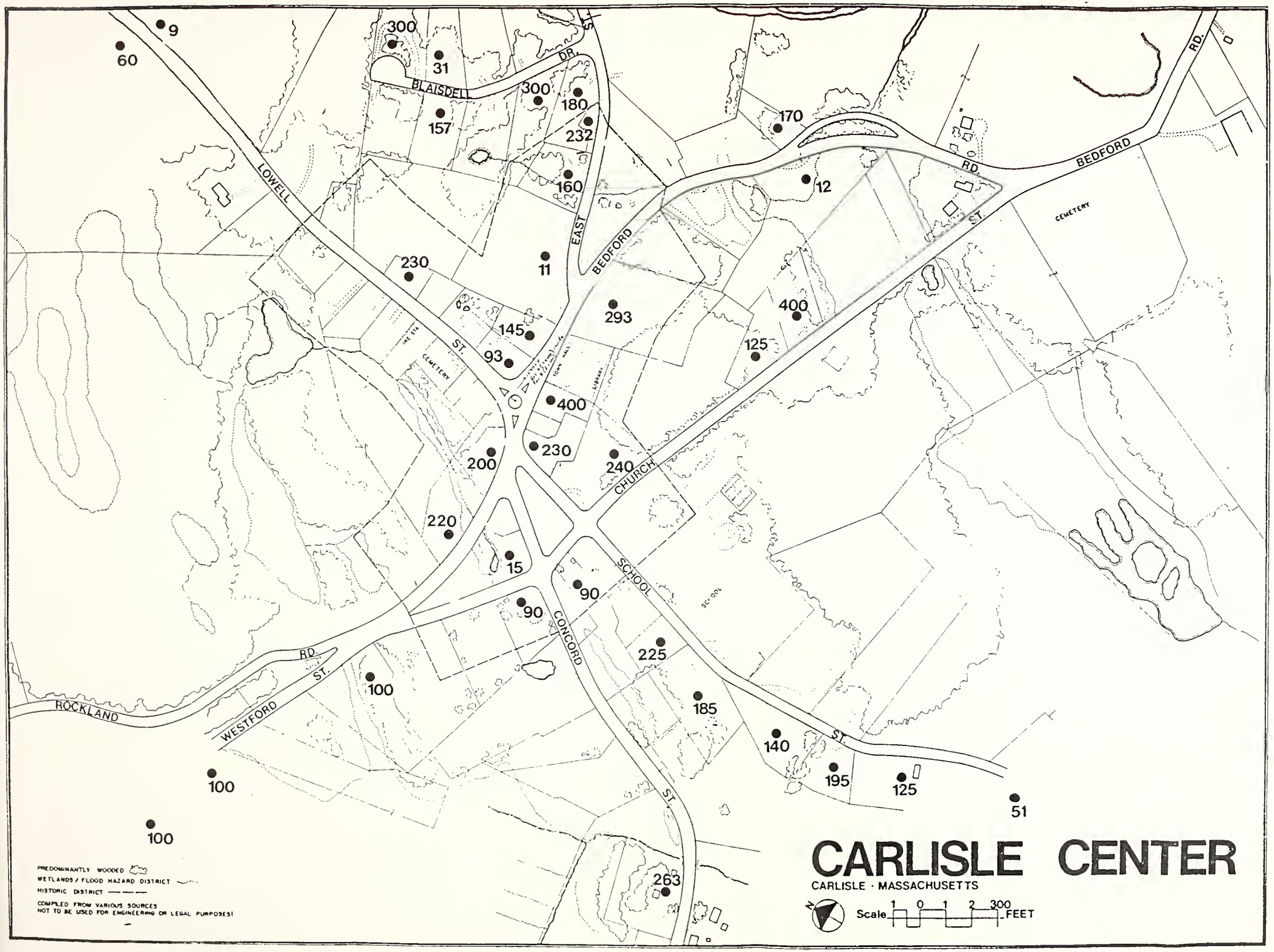
- Till
- Sand
- Sand and Gravel
- Swamp Deposits

Source: Calwell and Arora, 1973

Figure 2-3

WELL DEPTHS IN CARLISLE CENTER

(feet)



CHAPTER 3

EXISTING WATER QUALITY PROBLEMS

The quality of the groundwater drawn from wells in Carlisle center has been seriously affected by at least three types of contamination in the past several years. Since the mid 1970's, increased levels of sodium chloride have been detected in study area wells. In 1978, a leaking underground fuel tank contaminated several wells in the town center. And in 1983, a well in Carlisle center was closed due to bacterial contamination. Existing data on water quality have been reviewed, and the causes, extent, and impact of contamination have been evaluated.

SODIUM CHLORIDE CONTAMINATION

Existing Conditions. The most widespread and persistent water quality problem in Carlisle is salt contamination, evidenced by elevated levels of sodium and chloride. The results of sodium and chloride testing indicate that extremely high levels of salt have infiltrated the aquifer in the study area. In order to determine the cause of this contamination, a number of studies and surveys have been undertaken since 1977, including work by the Enviromental Protection Agency[1] (EPA) and the town's consultant[2]. Information was also obtained from work by IEP[3] and Caldwell and Arora[4]. Data compiled from these sources includes water quality samples from about 45 wells, soil borings, data on well depths and location, and hydrogeologic data such as water table elevation, groundwater flow, and geology. This data strongly suggests that the cause of sodium contamination is the former town road salt storage pile, located in the DPW yard.

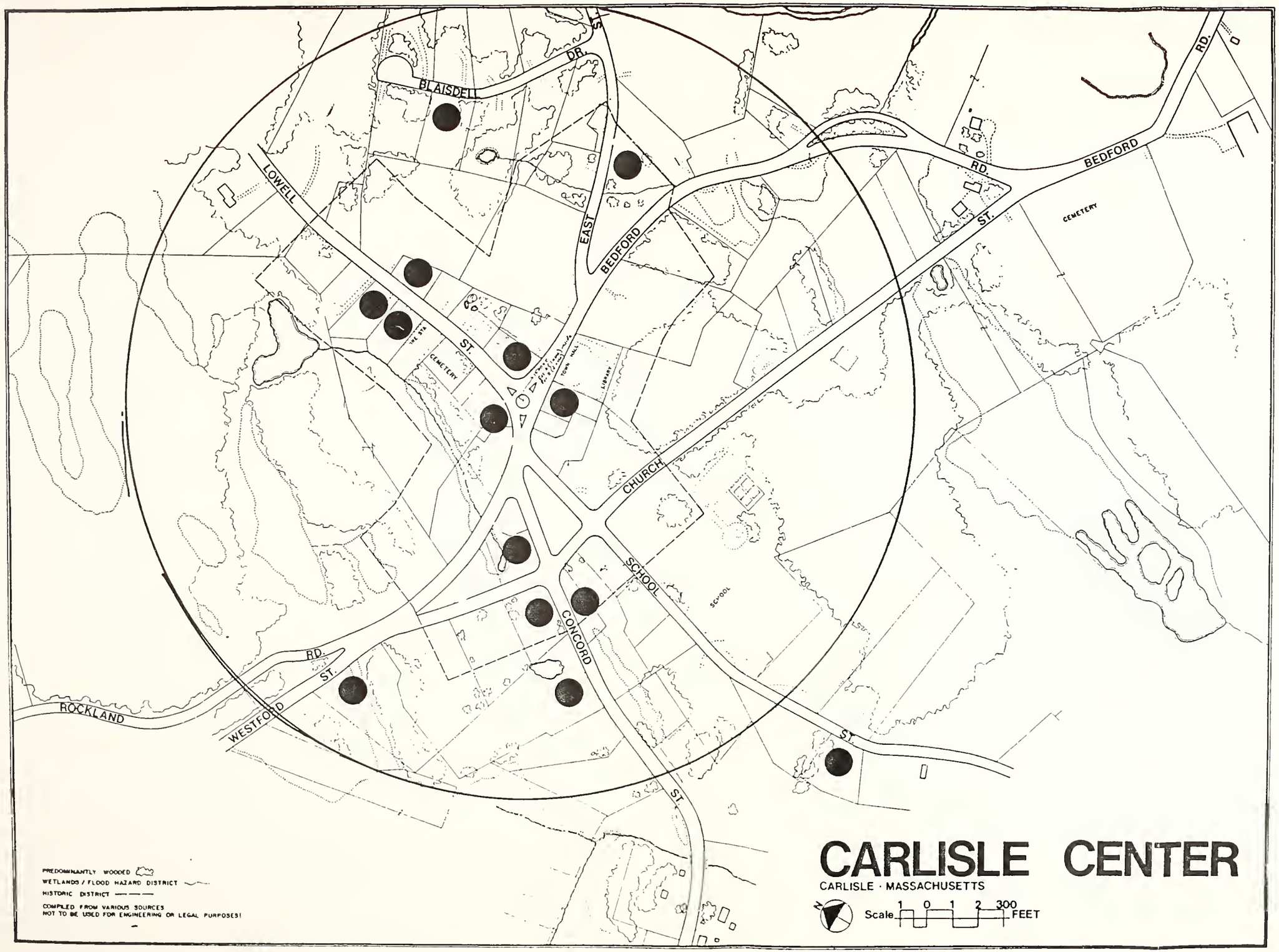
However, these studies taken together do not form a uniform data base, due to their different (and sometimes undocumented) methodologies, sampling points, and time frames. Therefore, from the larger grouping of water quality data points, a core group of 15 sample wells was selected, for which relatively uniform and regular sampling data exists over a five year period, from 1978 to 1983. The location of these sample wells is shown on Figure 3-1.

Samples from these 15 wells since 1977 have shown sodium concentrations of up to 500 milligrams per liter (mgl), with an average concentration of 90 mgl in the 15 wells for the period 1978 to 1983 (See Figure 3-2 and Table 3-1). Safe drinking water standards set a limit of 20 mgl for sodium, above which public water suppliers must notify customers of elevated sodium levels, for the benefit persons on sodium-restricted diets. However, since Carlisle does not have a public water supply, the Safe Drinking Water Act standards do not apply. The standards can nevertheless serve as a guide to the severity of the problem. Fourteen of the 15 well samples exceed the sodium standard.

It should be noted that although sodium levels in Carlisle exceed the recommended standar of 20 mgl, such levels pose a significant health hazard only to persons on sodium-restricted diets. For comparative purposed the average sodium level in Carlisle wells in 78 mgl, and the maximum level is 183 mgl, while milk contains about 480 mgl sodium. Nevertheless, the sodium levels in Carlisle are undesirable over the long term, in that they increase the dietary intake of sodium, which most medical research indicates should be minimized.

Figure 3-1

SAMPLE WELLS IN CARLISLE CENTER

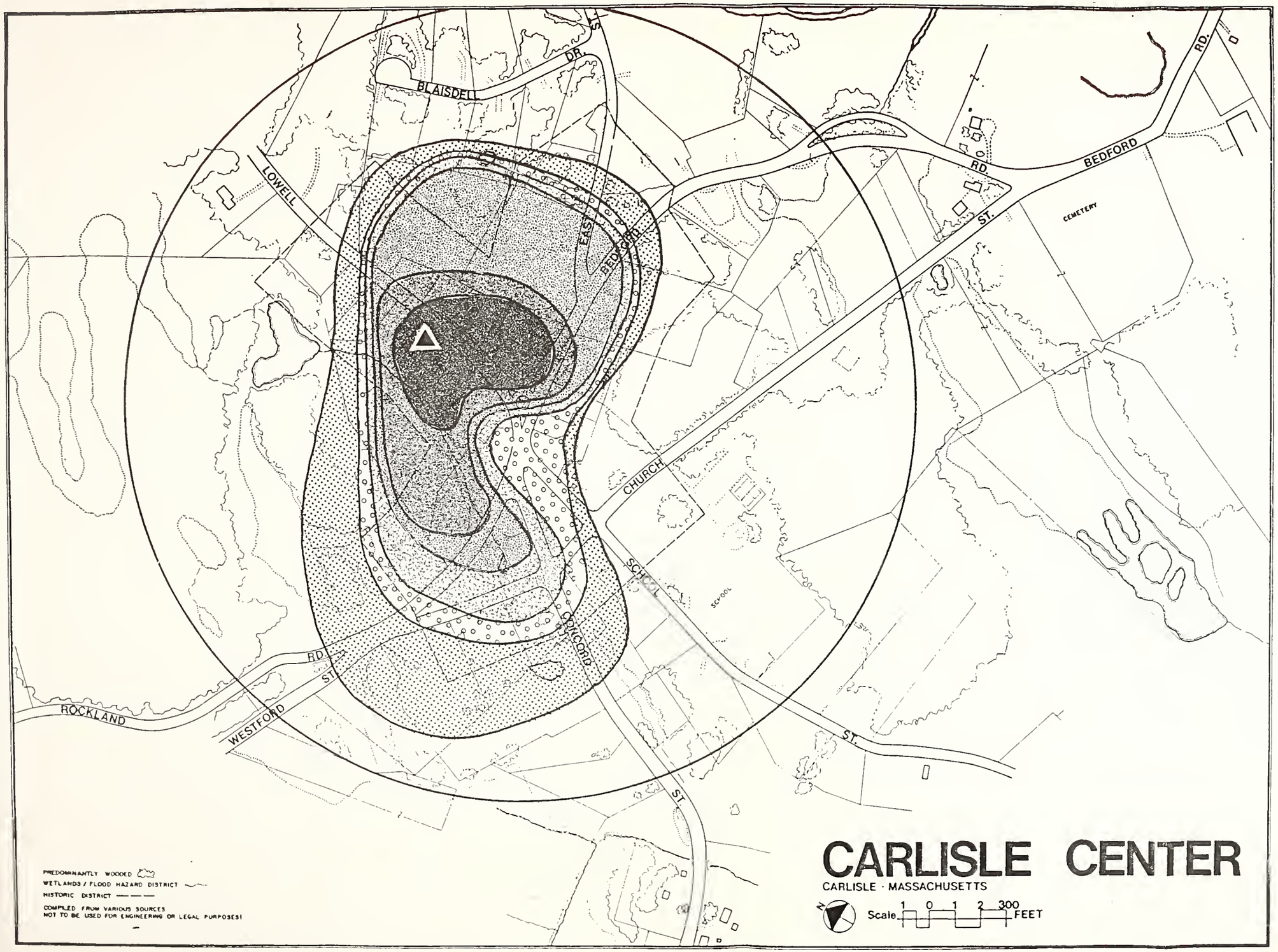


SAMPLE WELLS

STUDY AREA BOUNDARY

Figure 3-5

SODIUM CONTAMINATION OF GROUNDWATER



50-75 mgl

75-100 mgl

100-125 mgl

125-150 mgl

150-200 mgl

200 + mgl

▲ SALT PILE

DATA BASED ON
5 YEAR AVERAGE
SODIUM LEVELS
1978-1983

FIGURE 3-2

Sodium levels from 15 sample wells in Carlisle Center 1978 – 1984

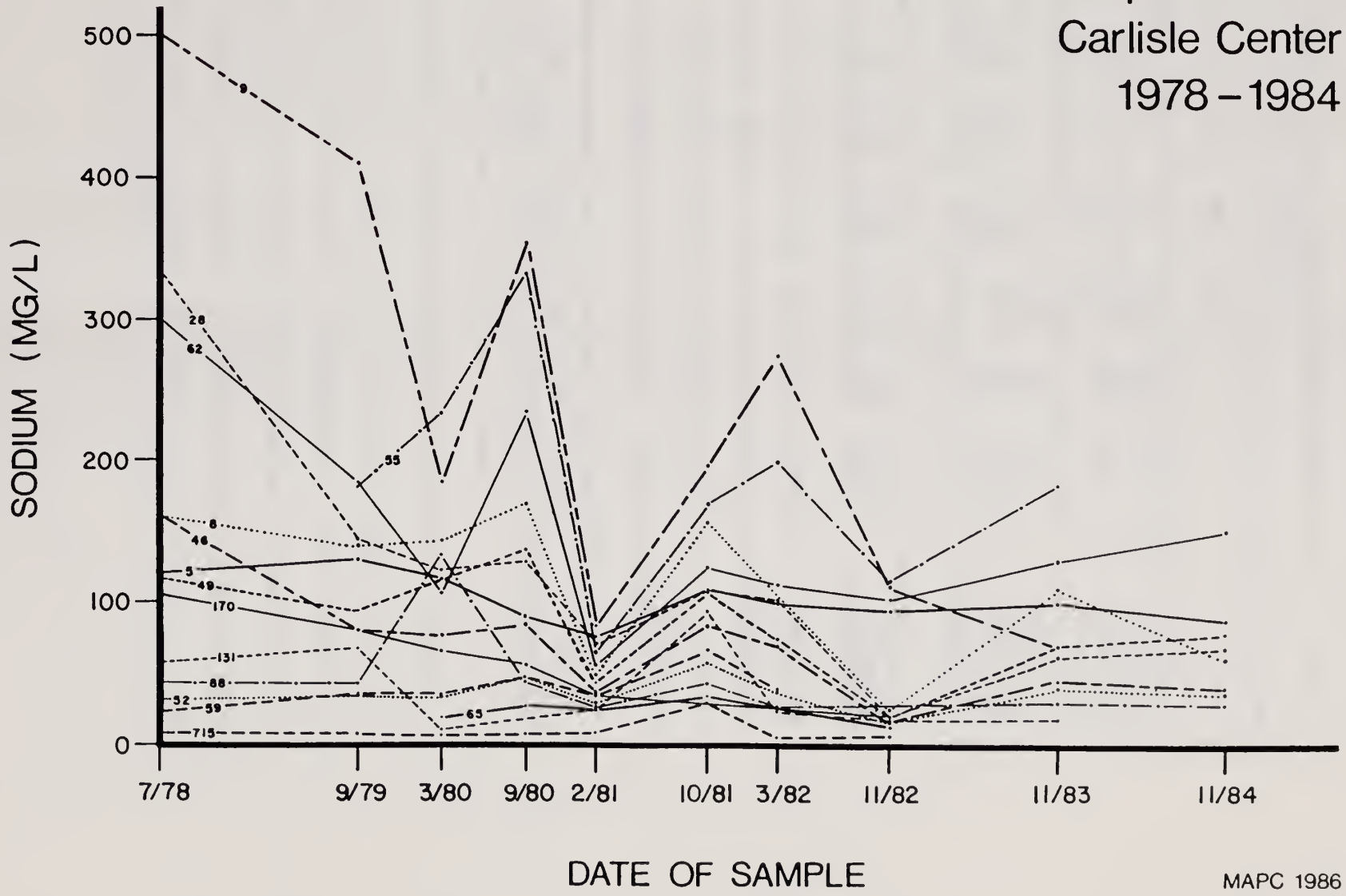


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Table 3-1 Sodium Levels in Carlisle Wells, 1978-1983
(milligrams per liter)

Sample	7/78	9/79	3/80	9/80	2/81	10/81	3/82	11/82	11/83	11/84
5 Lowell	120	130	117	90	77	110	100	95	100	86
55 Lowell	-	180	233	332	64	170	200	116	183	130
62 Lowell	300	184	107	235	56	125	112	101	130	150
65 Lowell	-	-	19	28	24	33	-	13	-	12
28 Concord	332	145	122	129	71	109	103	20	62	66
46 Concord	160	69	68	85	38	84	70	17	46	30
49 Concord	116	93	-	138	42	109	74	20	70	82
88 Concord	43	43	133	45	26	43	27	-	30	33
8 Bedford	160	140	143	170	49	157	-	25	110	64
9 Bedford	500	410	185	355	84	198	275	111	70	45
715 Bedford	8	8	7	8	9	30	4	7	-	-
170 School	104	80	66	57	34	-	-	20	-	-
131 Westford	58	68	10	-	24	94	24	18	19	-
52 East	31	36	36	48	30	59	38	15	40	36
59 Blaisdell	22	37	37	48	34	68	40	-	-	-
Average	150	116	91	126	43	99	89	44	78	67

Another indication of salt contamination is chloride. In the 15 sample wells, chloride averaged 266 mgl between 1978-1983, with a maximum level of 805. The standard for chloride is 250 ppm; six of the 15 sample wells exceed this limit (See Table 3-2).

The sample data shows that there have been fluctuations in sodium levels over the past five years, although on average, the long term trend appears to be a gradual decline in sodium concentrations. Average concentrations for the 15 wells were at a high of 150 mgl in 1978, and have since declined to 67 mgd by 1984 (see Figure 3-3). The maximum concentration declined from 500 mgl to 183 mgl over the same five year period. Most of the samples have been taken in the early spring and in the fall. There appears to be some seasonal fluctuations in the sodium levels, with the spring levels in each year case being lower than the preceding fall. When spring and fall samples are averaged in each calendar year, a more steadily declining sodium level is evident (See Figure 3-4). Perhaps sodium levels rise each fall because pumping of wells throughout the summer induces more movement of sodium through the aquifer (See discussion below of groundwater movement).

The sample wells also indicate the geographic pattern of dispersion of sodium contamination in the study area. This pattern suggests that the former road salt pile is the source of contamination. There appears to be a widening oblong plume of sodium enriched groundwater originating from the former salt storage site near the fire house, extending about 700 feet to the north, 1200 feet to the south, 600 feet to the east, and 300 feet to the west. (see Figure 3-5).

Table 3-2 Chloride Levels in Carlisle Wells, 1978-1983
(milligrams per liter)

Date of Sample	7/78	9/79	3/80	9/80	2/81	10/81	3/82	11/82	11/83	11/84
5 Lowell	740	547	496	413	484	523	447	511	380	330
55 Lowell	-	1131	988	693	638	807	796	766	600	600
62 Lowell	427	444	304	705	425	417	277	362	390	390
65 Lowell	-	-	40	77	110	97	-	85	-	30
28 Concord	831	330	210	162	476	157	190	170	136	93
46 Concord	270	170	166	203	163	154	145	149	83	77
49 Concord	250	192	-	173	159	178	161	149	120	110
88 Concord	200	205	177	176	152	170	161	-	140	140
8 Bedford	575	349	287	306	271	452	-	284	210	200
9 Bedford	1150	774	383	596	725	514	610	447	130	260
715 Bedford	10	8	3	4	12	18	16	7	-	-
170 School	160	135	90	89	99	-	-	120	-	-
131 Westford	160	206	19	-	69	175	67	142	37	-
52 East	120	148	134	140	174	152	140	142	130	-
59 Blaisdell	68	138	121	213	155	105	-	-	130	

FIGURE 3-3

Average sodium levels in 15 Carlisle wells

(milligrams per liter)

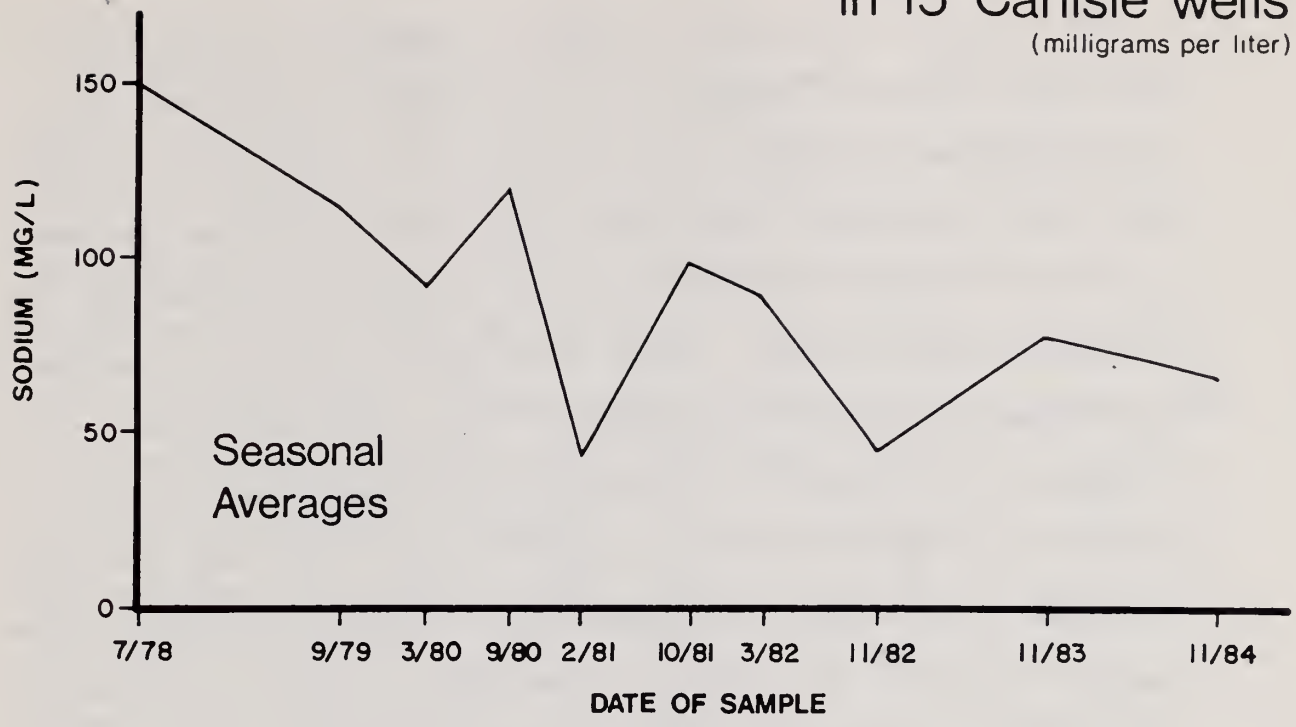
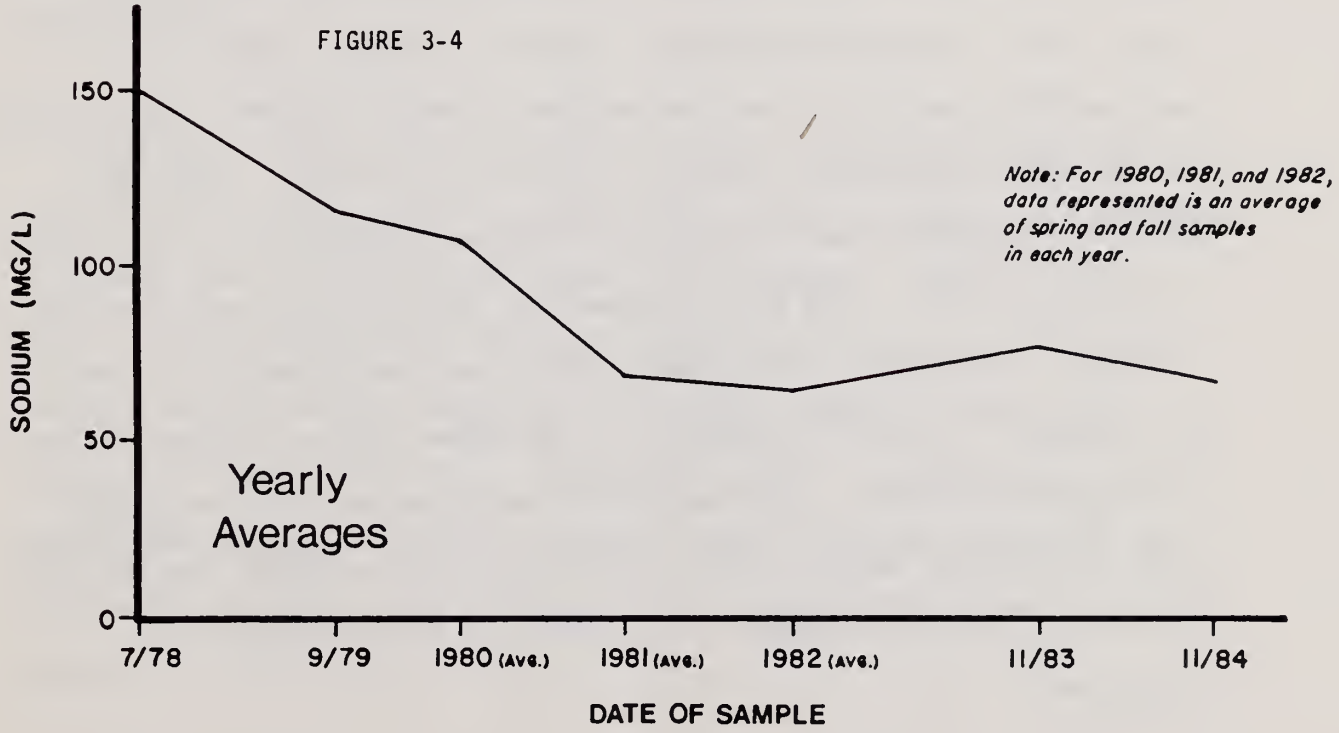


FIGURE 3-4



Note: For 1980, 1981, and 1982, data represented is an average of spring and fall samples in each year.

The direction of the plume's movement is apparently at odds with the water table gradient as mapped by IEP in the study of the Conant land.[5] That study showed the former salt storage area as a low spot in the water table, with groundwater flowing west, toward that area rather than east, away from it. However, there are at least two possible explanations for this apparent contradiction. First, there may be seasonal fluctuations in the groundwater gradient and direction of flow, and these may be influenced by the number of wells pumping in the immediate vicinity. Particulary during the dry summer months, the water table may lower, and pumping wells may reverse the gradient and direction of groundwater flow from west to east in the vicinity of the former salt pile. (This would also explain the seasonal fluctuations described above).

Yet another explanation was offered by a geologist at the U.S. Geological Survey.[6] This involves distinguishing between the local "water table" aquifer--groundwater stored in the upper layer of unconsolidated materials--and the regional "bedrock aquifer"--water stored in the underlying bedrock formation, mostly in fractures. The USGS geologist suggested that there may be different directions of groundwater flow at each level. The IEP map shows the "direction of local groundwater flow"-the flow nearest the surface in the water table aquifer. However, the "regional" flow of groundwater in the deeper bedrock aquifer may be in a different direction. This regional flow may be carrying the sodium plume to the deep bedrock wells in Carlisle center, despite the fact that the shallow local groundwater flow appears to be in the opposite direction.

In addition to the data from the 15 sample wells, other evidence points to the former salt storage pile as the source of contamination. In 1979, a consultant for the town sampled groundwater at the DPW yard, and found sodium levels of 2700 mgl in the DPW yard, 1350 mgl at a distance of 50 to 75 feet from the DPW yard, and declining to 520 mgl 140 feet from the DPW yard. The consultant concluded that the "DPW yard seems to be the major source of the saline ground water pollution in the area," and recommended taking soil samples[7]. These were conducted in 1981, and they indicated high levels of soidum in the soils in the DPW yard as well as in the vicinity. The consultant concluded that "the surface soils of the DPW yard are of significant salt levels, and in all likelihood will continue to leach salts into the groundwater" However, he also concluded that "the salt levels in the water are higher that those found in the soils, and data indicates that most of the salts are in solution in the groundwater[8]."

Salt was stored in an open pile in the DPW yard between 1958 and 1971, after which it was moved to a covered shed at the transfer station outside the study area. During the 14 years it was stored in the DPW yard, a total of about 2780 tons of salt was stored on the site (see Table 3-3). Several years after the salt pile was removed, elevated sodium levels appeared in town center wells. Considering the slow movement of groundwater through an aquifer (usually several feet per year), it is reasonable to expect a lag time before the contamination shows up in area wells.

Table 3-3

Historic Use of Road Salt in Carlisle

Year	Road Salt (tons)
1958	170.00
1959	92.76
1960	62.80
1961	69.00
1962	91.50
1963	129.76
1964	87.80
1965	143.90
1966	172.80
1967	165.40
1968	183.00
1969	415.80
1970	477.60
1971	520.00

Finally, in 1979, the Environmental Protection Agency (EPA) conducted a study of Carlisle's salt contamination. Samples from 43 wells were analyzed for sodium and chloride, and a regression analysis was performed to correlate contaminant levels with distance from the old salt site and distance from the streets. The results of the regression showed a high degree of correlation between sodium levels and distance from the old salt pile ($r = .82$) and a moderate correlation between sodium levels and distance to the nearest street ($r = .42$).

The EPA study concluded that there are large amounts of salt which have leaked into the groundwater in the vicinity of the DPW site, and that it will take years for salt concentrations to reach normal levels.

Considering the evidence of water quality monitoring and past studies, it is apparent that, whatever the exact mechanism of dispersal, a high-sodium plume does exist in the town center. Measured concentrations have been cut in half over a five year period, probably due to dispersion and dilution. This natural decrease in sodium concentration will probably continue, although it is not possible to predict future rates of decline, or how long it will take for levels to fall below the standard of 20 mgl, if ever. For, the foreseeable future, sodium levels will remain well above the drinking water standard in some Carlisle center wells. The town could consider several courses of action to deal with the problem. These are discussed in the following section.

It should be noted that, although road salt storage is the major cause of Carlisle's current problem, other potential sources of sodium contamination include application of road salts and septic systems. In Carlisle center, calcium chloride has been substituted for sodium chloride as a road deicing chemical for several years, so this is not currently a threat. However, sodium is a common constituent of septic system effluent. Considering the density of septic systems in Carlisle center, it would be advisable for the town to take steps to insure the proper operation and maintenance of septic systems. This is discussed in Chapter 4.

Recommendations. The town should continue to monitor wells in Carlisle center in order to determine the status of sodium contamination in the future. A group of about 15 wells have been monitored fairly consitently for the past five years; these form a database which indicates a long-term trend in sodium levels. Sampling should continue at least annually (in the fall) in order to monitor future trends and determine appropriate actions for individuals and the town to take. The well samples should be tested for sodium and chloride content.

As long as sodium remains a problem, the town should continue to use calcium chloride for road deicing in Carlisle center. While not the principal cause of elevated sodium in groundwater, application of road salt in the town center could contribute to the problem and retard the natural recovery of the aquifer.

The town could consider options for rehabilitating the aquifer, although these would be costly, and may not yield immediate results. This would include excavation of the salt-contaminated soils in the DPW yard, as well as a pumping operation designed to flush the sodium from the aquifer. Both of these operations pose the difficult problem of disposing of soil or water contaminated with high levels of sodium. Further, because of the unpredictable fracture pattern of the bedrock aquifer, it may be difficult to establish a pumping regimen which would thoroughly rehabilitate the aquifer. Detailed site engineering and hydrogeologic work would be required to design a rehabilitation program and measures to dispose of salt-contaminated soil and water.

Further engineering evaluations would be necessary to determine if such measures would be effective, and their cost. If the town wished to investigate this alternative further, it could contract with a consulting engineer to conduct a feasibility study which would evaluate the costs and benefits of an aquifer rehabilitation project.

As a final option, the town could consider developing a central water supply for Carlisle center if the contamination is not abated in a reasonable period of time, and if rehabilitation of the aquifer is not feasible. However, this would be a very costly option, and in a few years it may prove unnecessary if the sodium levels continue to decrease. However, once developed, the town would be committed to the maintenance and operation of the system. Therefore, this alternative should only be considered as a long term solution if sodium levels do not fall within reasonable limits naturally or through rehabilitation efforts.

GASOLINE CONTAMINATION

Existing conditions. In 1978, underground fuel storage tank in Carlisle center leaked gasoline into the ground, resulting in the contamination of about six private wells. One well was abandoned and replaced, and several others required the addition of treatment facilities for continued operation. Measured gasoline contamination reached a high of 40 milligrams per liter (mgl) in August of 1978 (See Table 3-4).

Table 3-4 Gasoline Contamintation
(milligrams per liter)

Date of Sample	Carlisle Superette	8 Bedford Rd.	23 Bedford Rd.
8/14/78	4	-	-
8/31/78	40	-	-
9/25/78	20	-	-
10/18/78	10	1.6	-
10/24/78	16	4	-
11/21/78	10	1.6	-
12/05/78	4.4	3.5	0.3
12/12/78	2.6	2.3	0.2
1/05/79	15	2.4	0.26
3/20/79	12.6	1.7	4.6
9/14/79	5.1	0.05	0.6
1/14/8	19	0.013	5.8

It is not known how much gasoline leaked from the tank. Remedial actions taken by the oil distributor included digging three trenches and installing a pump to recover spilled oil from the ground. New tanks were also installed. A water filtration unit was installed at Kelly Real Estate to reduce gasoline concentrations. In 1980, the filter unit reduced gasoline levels from 1.5 mgl to 0.18 mgl.

Although this was a single isolated contamination incident which did not have a widespread impact on the town, it points out the potential for groundwater contamination from all underground fuel tanks. A larger leak could have much more serious impacts on the town, including the need to abandon many wells and develop a central water supply using other sources.

Recommendations. To prevent future fuel leaks with serious consequences for the town's water supply, Carlisle should adopt an Underground Fuel Storage bylaw. Such a bylaw would require tank registration, corrosion protection on all new tanks, inventory verification, tank testing, and guidelines for tank location. The proposed bylaw is described in more detail in the next chapter, and a model bylaw is provided in Appendix A.

BACTERIAL CONTAMINATION

In 1983, the Carlisle Board of Health reported that a well in Carlisle was condemned due to coliform bacteria contamination. The well was a shallow (12 foot) dug well, and was uncovered. Possible sources of contamination include manure and septic system effluent. This incident illustrates the potential problems of a densely developed area which relies on both on-site wells and septic systems. Chapter 4 contains recommendations for maintenance of private wells and septic systems.

CHAPTER 4

LAND USES AND WATER SUPPLY IMPACTS

Land uses can affect both ground water quality and quantity through physical alteration of the environment, which changes drainage patterns and rates of runoff and recharge, and through discharge of contaminants to surface or groundwater. In this chapter, the potential impacts of land uses on water supplies are analyzed in terms of the physical alterations and chemical contaminants associated with each. For each of these potential sources of contamination, the analysis presents:

- o the characteristics and water supply impacts,
- o the land uses associated with each,
- o existing conditions in Carlisle Center describing the prevalence of these land uses, and
- o recommendations for improved management or regulation for water supply protection.

The potential sources of contamination addressed area: runoff and storm drainage, waterwaste, underground fuel storage tanks, road salts, and hazardous materials and wastes.

As illustrated in Table 4-1, approximately 33 percent of the study area is undeveloped. This land has potential for future development. Such primarily undeveloped property provides a natural recharge area for groundwater and surface water and this has no adverse effect on either the quantity or quality of drinking water supplies.

The developed land uses in the town have the potential to cause impacts on the quantity and quality of water supply in Carlisle. These impacts area decribed in the remainder of this chapter.

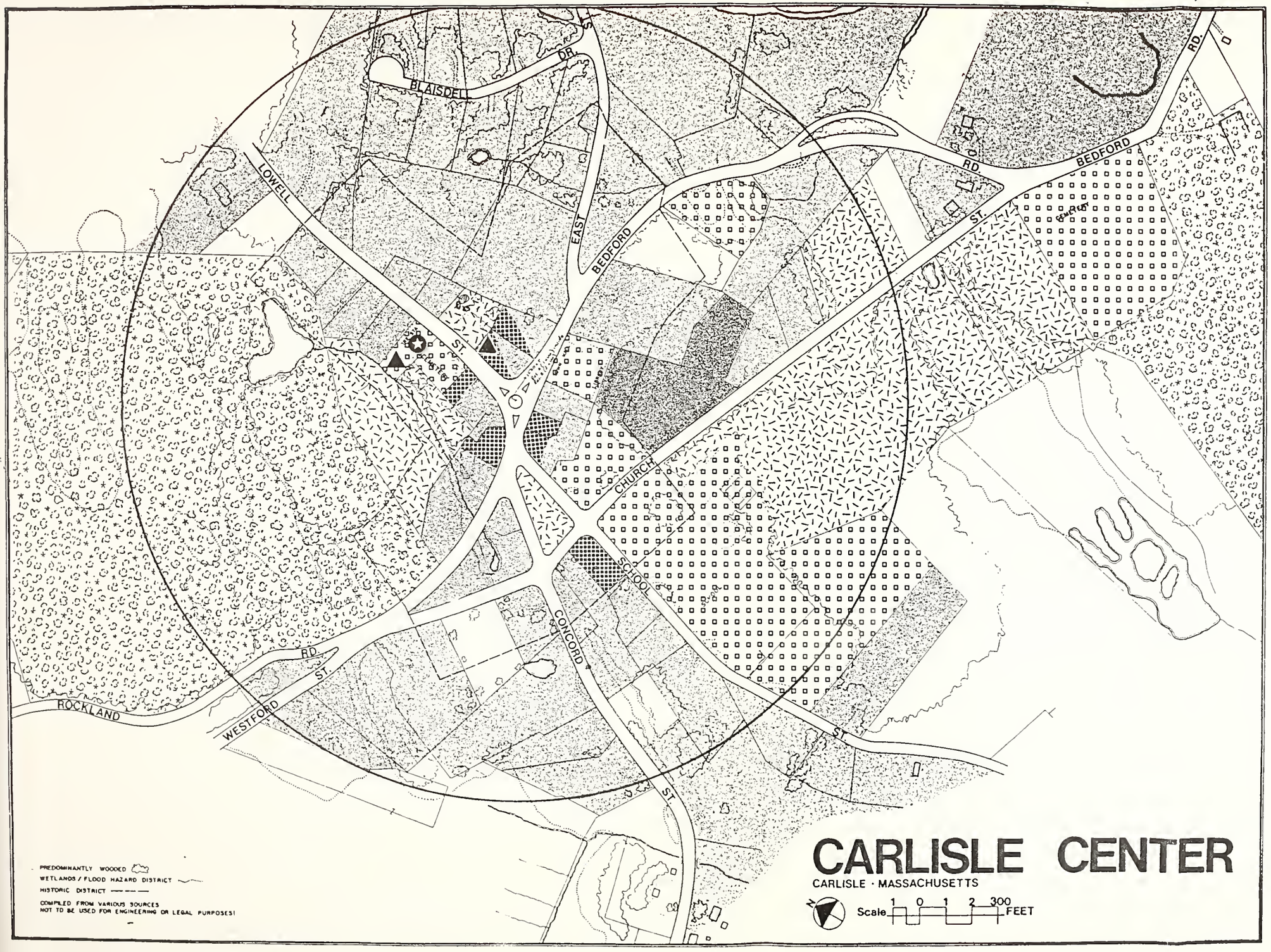
Table 4-1

Carlisle Center Land Use

Land Use	Acres	Percent
Residential	86	53
Institutional	19	12
Commercial	2	1
Developed	107	66
Town	14	9
Conservation	33	20
Vacant	8	5
Undeveloped	55	34
TOTAL	162 acres	100%

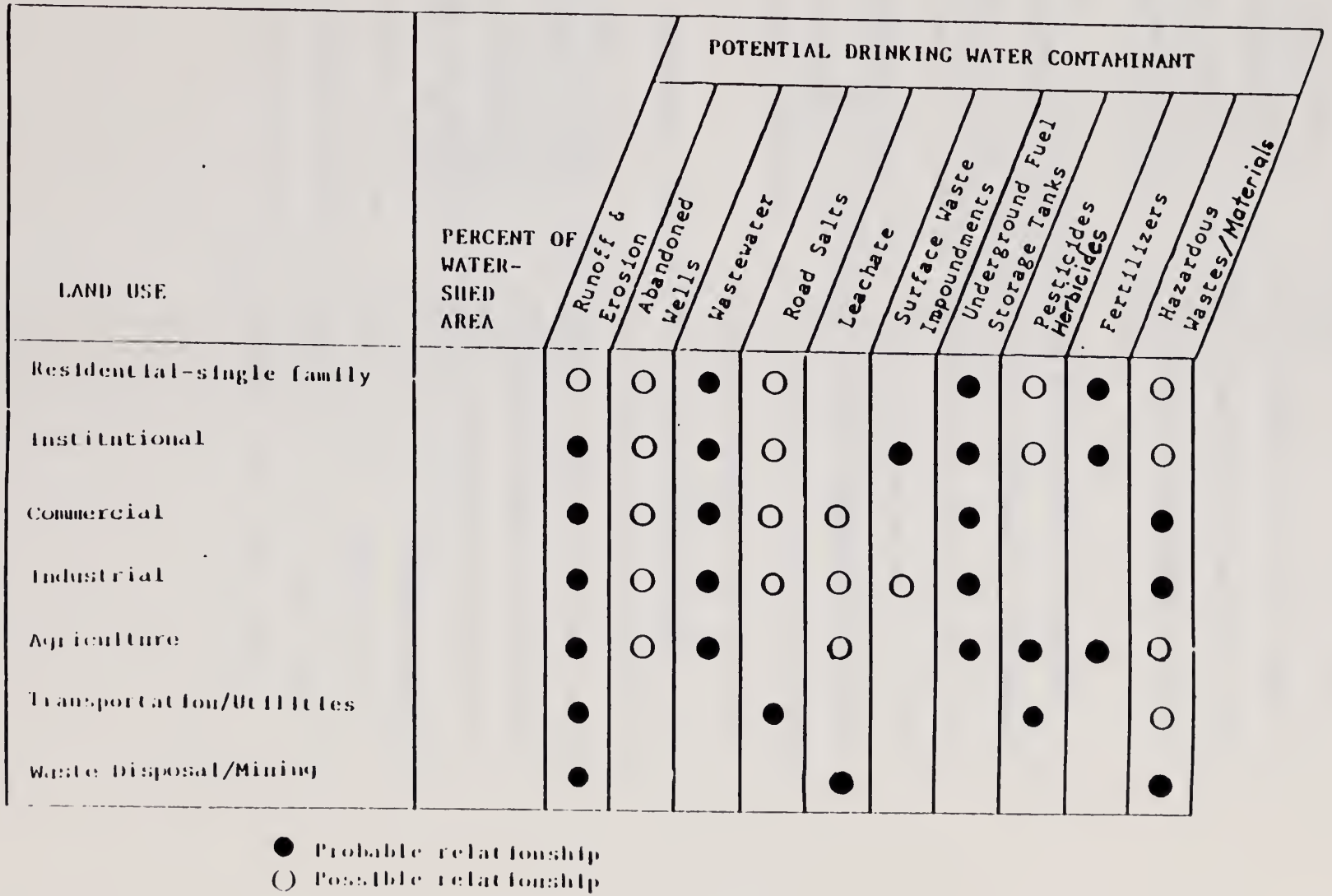
Figure 4-1

LAND USE



- INSTITUTIONAL
- TOWN LAND
- CONSERVATION LAND
- RESIDENTIAL
- ELDERLY RESIDENTIAL
- COMMERCIAL
- FORMER DPW SALT PILE
- UNDERGROUND FUEL TANKS
- STUDY AREA BOUNDARY

FIGURE 4-2 EFFECTS OF LAND USES ON WATER SUPPLY SOURCES



a. Characteristics and Water Supply Impacts. Runoff is rainfall that is intercepted by impervious surfaces and carried away as surface flow. As runoff flows over surfaces, it picks up contaminants such as road grit, salt, fertilizers, pesticides, and oils, and is discharged to ponds, streams or wetlands either directly or through a system of storm drains.

Runoff and storm drainage can affect both the quantity and quality of groundwater. Impervious surfaces increase the surface runoff of precipitation, which in turn reduces the amount of water which infiltrates the soil and recharges the aquifer. This loss of recharge can lead to a lowering of groundwater levels, particularly during dry periods. Groundwater quality can be affected by contaminants picked up by runoff which later infiltrates to an aquifer.

b. Land Use Associations. Institutional, commercial, residential, and transportation uses have the potential to affect water supplies through runoff. Developed, or urbanized, land uses tend to have high runoff rates and create the potential for contamination by runoff, while construction activity itself creates the potential for erosion and increased runoff.

c. Existing Conditions. Approximately 66 percent of land within the study area is developed. Of this total, about 53 percent is developed as residential and the remainder contains more intensive uses such as institutional, commercial or transportation.

d. Recommendations. The existing regulations give fairly broad powers to a the planning board for control of runoff and erosion. Given the amount of undeveloped land in the town, it will be important to continue to enforce the existing regulations. In addition, the subdivision regulations could be amended to afford greater protection to groundwater data and mitigation measures in plan submissions in certain cases. These amendments are detailed in Chapter 5.

In addtion, runoff can be reduced by lower lot coverage requirements. This is addressed in Chapter 5.

WASTEWATER

a. Characteristics and Water Supply Impacts. Both surface and groundwater supplies can be affected by problems associated with disposal of sanitary wastes. Failing septic systems can be caused by improper siting, installation or maintenance. Soil type, depth to bedrock and depth to the water table can be major factors in spetic systems failures. Such failure can introduce excessive nutrients, chlorides, bacteria and household chemicals into soil which can then leach into water supplies.

Proper care and maintenance of septic systems is also vital to groundwater protection. Periodic pumping of the septic tank is necessary to proper system operation and to avoid failures which could pollute groundwater.

b. Land Use Associations. Residential, commerical, and institutional uses generate sanitary wastes. These land uses occupy 107 acres, or 66 percent of the study area.

c. Existing Conditions. The entire town of Carlisle is serviced by private on-site septic systems. In Carlisle center, there are about 30 septic systems on file with the Board of Health. There are no records of septic system failures in the study area. One well outside the town center was condemned in 1983 due to coliform bacteria, but the cause of contamination is not certain. Considering the density of development and the reliance on both septic systems and on-site wells in Carlisle center, there is the potential for water supply contamination if septic systems are not properly maintained.

d. Recommendations. In order to protect its groundwater supply, the town should encourage proper septic system maintenance practices. Public education should be provided regarding the need for periodic pumping of the septic tank, proper disposal of hazardous materials, and septic tank inspection.

The Board of Health could informally monitor the voluntary program by mailing out reminders with a mail-back response post card attached. Appendix B contains a model program description.

UNDERGROUND FUEL STORAGE

a. Characteristics and Water Supply Impacts. Gasoline and other fuels stored in an underground tank may contaminate groundwater if the tank develops a leak due to puncture or corrosion. Corrosion rates are dependent on the corrosivity of the soil and tank type. Most soils in Massachusetts are considered to be highly corrosive. In corrosive soils, unprotected steel tanks may have an average lifespan of 15 to 20 years, although leaks have developed in tanks as early as 10 years.

Several types of tanks resist corrosion. These include fiberglass tanks, coated steel tanks, cathodically protected tanks, and double-walled tanks. All of these are preferable to unprotected steel tanks in corrosive soils.

b. Land Use Associations. Underground storage tanks are typically located at service stations, fuel companies, highway department garages, car dealerships, garages for commercial car and truck fleets, schools, churches, large apartments, hospitals and other institutions, and at residencies when large heating oil tanks are desired for additional storage capacity. The associated land uses in Carlisle are therefore commercial, institutional and residential.

c. Existing conditions. In Carlisle center there are six underground fuel tanks containing gasoline or diesel fuel. These are listed below in Table 4-2. Three of these tanks are located at the Carlisle police and fire departments. The others are at Carlisle repair. These are all steel tanks with no corrosion protection. As mentioned above, a 1978 leak at Carlisle Repair contaminated several private wells. Tanks at that location have since been replaced. Because of the close proximity of many private wells, leaks at any of the existing tanks, or at any new tanks installed in Carlisle center, have the potential to seriously harm the town's center's water supply.

Table 4-2 Underground Fuel Tanks

Owner	Tank Size	Tank Material	Contents
Carlisle Repair	7500	Steel	Gasoline
	7500	Steel	Gasoline
	2000	Steel	Gasoline
Fire & Police Dept.'s	2000	Steel	Gasoline
	1000	Steel	Gasoline
	2000	Steel	Diesel fuel

d. Recommendations. In order to protect the town's water supply from contamination by leaking underground fuel tanks, the town should adopt a general bylaw regulating underground fuel storage tanks. Such a bylaw would incorporate the existing provisions of the Massachusetts Board of Fire Prevention regulations, and include requirements for tank testing (leak detection), and spill contingency plans. A model underground fuel storage bylaw has been prepared by MAPC and appears in Appendix A. This bylaw can be adopted by the town under its home rule powers to protect the public health and welfare, and under the authority of Massachusetts.

ROAD SALTS

a. Characteristics and Water Supply Impacts. Deicing chemicals such as sodium chloride applied to roads in winter or stored in uncovered piles can wash off pavements into surface water bodies or percolate through soils to groundwaters. Since standard water treatment systems are unable to remove sodium chloride from drinking water, sodium concentrations which may be harmful to the health of some individuals may result. Also, at high concentrations, chloride can corrode water distribution pipes and water fixtures. Therefore, the Massachusetts Department of Environmental Qualtity Engineering has set a health standard of 20 mg/l for sodium. DEQE requires regular sampling and analysis of sodium concentrations in public water supplies and notification of customers if the concentrations exceed the standard.

b. Land Use Associations. Land uses which are associated with use of road salts are transportation, for maintaining road safety in the winter, and residential, insitutional, commercial and industrial for clearing parking lots and private drives.

c. Existing Conditions. The town of Carlisle maintains roads in the town center. Since 1980, the town DPW has been using calcium chloride instead of sodium chloride in Carlisle center. Elsewhere in the town, a salt/sand mixture (one part salt to 12 parts sand) or pure salt is used.

b. Land Use Associations. Land uses which are associated with use of road salts are transportation, for maintaining road safety in the winter, and residential, institutional, commercial and industrial for clearing parking lots and private drives.

c. Existing Conditions. The town of Carlisle maintains roads in the town center. Since 1980, the town DPW has been using calcium chloride instead of sodium chloride in Carlisle center. Elsewhere in the town, a salt/sand mixture (one part salt to 12 parts sand) or pure salt is used.

Storage of road salt in the town has been moved from an open storage pile in the DPW yard to a storage shed at the transfer station. As discussed in Chapter 3, the former open salt storage pile is responsible for the sodium contamination of groundwater in Carlisle center.

d. Recommendations. The town should continue to use calcium chloride as a road de-icing chemical in Carlisle center. The town should use the minimum amount of salt consistent with highway safety in other parts of the town. This may be accomplished in part by covering the sand pile, so that less salt is needed to prevent the sand from freezing.

HAZARDOUS MATERIALS AND WASTES

a. Characteristics and Water Supply Effects. Hazardous wastes are wastes which are toxic, reactive, corrosive or ignitable. Improper handling of hazardous wastes is an obvious threat to water supplies. A less obvious source of hazardous wastes is what is commonly referred to as "household hazardous wastes". These include materials such as bleach,

mothballs, paint remover, oven cleaner, wood preservative, and used motor oil. Improperly disposed of, they can reach groundwater or surface water and result in contamination of water supplies.

Although hazardous wastes and materials are usually associated with industry, many small businesses may also store, use, or dispose of hazardous wastes and materials. These may include dry cleaners, photography labs, print shops, hair-dressing salons, and motor vehicle repair shops. In an unsewered area like Carlisle, any hazardous materials which go "down the drain"--either accidently or intentionally--may reach an aquifer and contaminate water supplies.

b. Land Use Associations. All developed land uses, including residential, commercial, and institional, have the potential to be associated with hazardous wastes and materials.

c. Existing Conditions. In Carlisle center, there are no large industrial or commercial sources of hazardous wastes or materials. One small business, a machine parts shop, may use materials which would be hazardous if improperly disposed of. The gas station is also a potential source of hazardous wastes. The most significant threat of contamination by hazardous wastes is that of the improper disposal of household hazardous wastes. There are at least several dozen homes with septic systems in the study area, each of which could potentially contribute hazardous wastes to the groundwater.

d. Recommendations. The town should provide public education to residents of Carlisle center about the proper disposal of household hazardous wastes. Copies of MAPC's brochure on household hazardous wastes will be provided to the town, for distribution to Carlisle residents.

The town should also consider organizing a household hazardous waste collection, such as that sponsored by Lexington, Bedford, and many other Massachusetts communities.

Regulation of future land uses associated with hazardous wastes and materials is addressed in the zoning recommendations in Chapter 6.

CHAPTER 5

PRIVATE WELL MAINTENANCE

Proper maintenance of wells is important to the continued delivery of good quality water. Many well owners may not be familiar with the operation of wells, sources of pollution, and options for testing and treating groundwater. MAPC and the Massachusetts Audubon Society have produced a well owners manual which could be useful to Carlisle residents. Copies of the manual will be provided to the town of Carlisle. The contents of the manual are outlined below, and some data from the manual is excerpted.

Private Well Owners Handbook

Summary of Contents

1. Groundwater and Wells

2. Types of Wells
   - o Dug
   - o Bored
   - o Driven
   - o Drilled

3. Well Yield and Pump Selection

4. Sources of Well Pollution
   - o Iron and Manganese
   - o Hardness
   - o Acidity
   - o Arsenic

5. Pollution from Human Activities
   - o Sodium
   - o Nitrates
   - o Bacteria
   - o Gasoline and oil
   - o Hazardous wastes
   - o Pesticides and fertilizers

6. Water Testing
   - o Who performs water quality tests?
   - o What if the well is polluted?

7. Water Treatment
   - o Bacterial control
   - o Hardness removal
   - o Iron and manganese removal
   - o Acidity
   - o Sodium
   - o Hydrogen sulfide
   - o Nitrate
   - o Trace metals
   - o Organics

8. Private Well Regulations

TABLE 5-1 SUMMARY OF WELL POLLUTION PROBLEMS

PROBLEM	POSSIBLE CAUSE	STANDARD	TYPICAL CORRECTIVE PROCEDURES
Odor			
General	Coliform or total bacteria	0 coliforms/100 mls	Chlorination, aeration, ultra-violet radiation, well relocation.
	Ammonia nitrogen	No standard	Well relocation, reverse osmosis.
	Manganese	.05 mg/l**	Zeolite-ion exchange, manganese green sand, birm, oxidation by aeration or chlorination.
Rotten egg odor	Hydrogen sulfide, sulfate reducing bacteria, sulfur bacteria. Check coliform.	0.5** hydrogen sulfide	Charcoal filter, hypochlorite green sand, potassium permanganate, regenerated oxidizing filter.
Gassy smell	Methane (indicates decay of organic matter).	3 odor threshold	Aeration, install gas release valve on pressure tank.
Chemical/oil smell	Indicates chemical pollution.	Chemical-specific	Depends on chemicals.
Chlorine smell/taste	Residual chlorine	Below 0.01 mg/l is recommended.	Flush well.
Taste			
General	Total bacteria, nitrite or ammonia nitrogen, possibly from decaying sewage or vegetable matter.	No general taste standard. Test for coliform (0/100 ml), nitrate (10 mg/l), and ammonia.	Distillation, reverse osmosis, or strong base ion exchange.
Salty taste	Chloride or sodium. Possibly from road salting or salt-water intrusion.	250 mg/l chloride** 20 mg/l sodium**	Same as above.
Bitter taste	Copper. May indicate pipe corrosion. Leaves green stains.	1 mg/l**. Check pH, chloride and sulfate.	Same as above. Replace pipes.
Metallic taste	Iron. Red particles settle when water is left standing.	0.3mg/l**	Carbon filter and chlorination, zeolite softener, oxidizing filter, sand filter, polyphosphate feeder, birm.

PROBLEM	POSSIBLE CAUSE	STANDARD	TYPICAL CORRECTIVE PROCEDURES
Appearance			
Cloudy water	Turbidity	1.0 turbidity unit	Coagulation, fine filtering, sediment filter, activated carbon filter.
	Bacteria	No limit total bacteria	Chlorination, aeration, ultra-violet radiation.
Rusty water	Iron	0.3 mg/l**	Zeolite softener, oxidizing filter, see above.
Rusty slime, clumps	Iron bacteria	No standard	Chlorination and filtration
Staining of clothes, fixtures, food or silverware (brownish-black)	Iron (reddish) or manganese (black)	0.3 mg/l iron** .05 mg/l manganese**	Treatment should match complete chemical analysis. See treatment for iron.
Noticeable bathtub ring, streaked, murky glassware, gray laundry, lots of soap needed to form suds.	Hardness	No limit; less than 100 mg/l hardness is recommended.	Correct with softener, which will increase sodium.
Corrosion	Sulfate (corrosive at low pH, especially when combined with chloride).	250 mg/l**	Distillation, reverse osmosis, strong base ion exchange.
Acidity (low pH)		pH 5.5 - 8.5** Below 5.5 - corrosive Above 8.5 may create scale problems.	Soda ash solution, Maclean system Neutralizing tank w/limestone chips - treatment will increase hardness as acidity decreases.
Laxative water	Silica may be laxative.	No standard	Reducing hot water temperature may help.
Tooth mottling	Excess fluoride. Found naturally in deep artesian wells.	1.4 - 2.4 mg/l. 1.0 is ideal.	Notify dentist. Distillation, reverse osmosis, strong base ion exchange.

** Secondary Standard: Recommended, not required for public drinking water supplies

Table 5-2 Summary of Common Water Treatment Methods and Maintenance Requirements

Treatment Method	Maintenance Tips
Water Softening Units	• Replenish the exchange bed (flush with brine) • Backwash periodically to remove buildup within exchange bed.
Reverse Osmosis	• Pretreat membrane to reduce maintenance • Replace membrane (1-3 years); acetate membrane more versatile than nylon.
Chemical Feed Pumps	• Check, clean, replace parts periodically (chemicals eventually degrade pump components) • Keep storage tank full
Ultra-violet Radiation	• Replace lamp (1-3 years) • Clean quartz sleeves periodically
Chlorinator	• No equipment to maintain • Measure residual chlorine weekly or monthly (if constant) • Store chlorine in cool, dark place in glass container
Filtration (activated carbon, neutralization)	• Replace medium at least yearly • Backwash system periodically to prevent clogging
(Iron Filters)	• Recharge oxidizing medium with potassium permaganate • Backwash periodically to flush collected iron
(Clarifying Filters) (sediment removal)	• Backwash periodically
(Birm)	• Backwash periodically. • Requires sufficient dissolved oxygen, pH requirements.

CHAPTER 6

DEVELOPMENT GUIDELINES

Chapter 4 examined the potential impacts of existing land uses on the tonw's water supply, and presented recommendations designed to mitigate those impacts. In this chapter, local regulations governing future development will be reviewed, and recommendations will be made to ensure that potential groundwater impacts are considered in future development decisions. The local development controls which will be examined are zoning, subdivision regulations, and site pland review.

ZONING

Carlisle's zoning bylaw defines three types of residential districts and two business districts, as well as a wetland/flood hazard overlay district. In Carlisle center there are three districts: Residence A, Residence M, and the Carlisle Center Business District. The use regulations and intensity and dimensional requirements of these are described below and summarized in Table 6-1. Figure 6-1 shows the location of the zoning districts in Carlisle center.

Residence A

Description. This is a one-acre residential district which permits one and two-family residences, as well as schools, churches, municipal uses, public utilities, recreation, agriculture, and home occupations. A special permit is required for hospitals, nursing homes, nursery shcools, kennels, cemetaries, and residents' small businesses.

FIGURE 6-1

SUMMARY OF USE REGULATIONS

Y = Permitted
N = Not Permitted
SP = Special Permit Required

Permitted Uses	DISTRICT General Residence[2]	Business[3]	Center Business[4]
One-family dwelling	Y	Y	Y
Conversion to 2-family (5)	Y	Y	Y
Non-profit school-public/private	Y	Y	Y
Municipal administration,recreation	Y	Y	Y
Public utility without service yard	Y	Y	Y
Church, parish house	Y	Y	Y
Agricultural use	Y	Y	Y
Showroom , stand for on-site products	Y	Y	Y
Resident's home occupation	Y	Y	Y
Hospital, charitable institution	SP	N	N
Nonprofit club, civic use	SP	SP	SP
Nursery school,day care	SP	Y	N
Convalescent or nursing home	SP	N	N
Municipal or private cemetery	SP	Y	Y
Other town or government use	SP	Y	N
Kennel, animal hospital	SP	SP	N
Commercial, open recreation	SP	N	N
Resident's small business	SP	Y	Y
School buses on town land	SP	Y	SP
School buses not on town land	N	SP	N
Retail stores	N	Y	Y
Showroom for building supplies	N	Y	N
Showroom for autos, boats,etc. (no repairs)	N	Y	N
Laundry or cleaning drop	N	Y	Y
Dressmaking or milliner	N	Y	Y
Household appliance repair	N	Y	Y
Interior decorating studio	N	Y	Y
Photographer's studio	N	Y	Y
Shoe or hat repair	N	Y	Y
Tailor shop	N	Y	Y
Bicycle or sporting goods repair	N	Y	Y
Barber or beauty shop	N	SP	SP
Funeral home	N	SP	N
Artisan's shop (with 1000 sq. ft. work area limit)	N	Y	Y
Business or professional office, bank	N	Y	Y
Auto or boat repair (enclosed)	N	SP	N
Restaurant (indoors)	N	SP	SP
Gas station	N	SP	SP
Light manufacturing related to retail (2,000 sq.ft. limit)	N	SP	N

(continued)

(1) Certain additional regulations may apply depending on location. See the following:
- overlay flood hazard and wetland districts (Sections 5.A. and 5.B.);
- land under 121 foot elevation (Board of Health regulations 1.1).

(2) See Section 3.B. of Bylaw for detailed description of permitted uses

(3) See Section 3.C. of Bylaw for detailed description of permitted uses

(4) See Section 3.D. of Bylaw for detailed description of permitted uses

(5) Dwellings existing on May 11, 1962 (See 3.B.1.b.).

Other commercial uses are prohibited. The maximum lot coverage permitted is 25 percent. Most of Carlisle center is zoned Residence A. Uses permitted by right and by special permit in this district generally do not pose a threat to groundwater quality.

The lot coverage requirement may impact groundwater quantity by increasing runoff and reducing groundwater recharge.

b. Recommendations. The Residence A district should be amended to allow a maximum lot coverage of 10 percent or 4000 square feet, whichever is greater, including all impervious surfaces such as structures and paved areas.

As a safeguard to the groundwater in Carlisle center, the use regulations for the Residence A district should be amended to include a prohibition on the following:

1. disposal of solid wastes, other than brush and stumps and dirt;
2. the disposal of liquid or leachable wastes, except domestic sanitary wastes and water in approved septic systems;
3. uses which discharge process wastewater on-site;
4. open storage of road salt or salt/sand mix;
5. dumping of snow containing deicing chemicals;
6. the storage of uncovered manure; and
7. the storage or disposal of hazardous wastes, as defined by Massachusetts General Laws, Chapter 21.

These provisions are taken from MAPC's model aquifer protection zoning bylaw.

CARLISLE CENTER BUSINESS DISTRICT

a. Description. This district permits as of right the uses allowed in the Residence A district, in addition to a host of business uses, including retail, shops, offices, and the shop of a printer, builder, carpenter, plumber, painter, and other craftsman. Special permits are required for barber or beauty shops and gasoline filling stations.

There is no minimum lot size for this district. Maximum lot coverage permitted is 75 percent.

Within Carlisle center, five parcels totalling about 2 acres are zoned for business. Within this district, the use with the most potential groundwater impact is gasoline filling stations. However, these potential impacts are addressed by the recommended underground fuel storage bylaw (See Chapter 4). Another potential impact of this district is the high lot coverage permitted, which may reduce groundwater recharge.

b. Recommendations. To insure that no business uses will have associated activities which could pollute the groundwater, the use regulation amendments recommended for the Residence A district above should also apply to the Carlisle Center Business District. To reduce runoff and loss of recharge, the maximum lot coverage in this district should be reduced from 75% to 50%.

a. Description. The subdivision regulations include requirements for submitting data on existing site features with the definitive plan. They also require proposed plans for storm drainage to be submitted. However, neither of these provisions includes a requirement for impacts on groundwater to be evaluated or mitigation measures to be proposed. While groundwater impacts may not be significant in every subdivision proposed, some proposals may have the potential to impact the quality or quantity of the groundwater due to the nature or location of the project. In such cases, it would be useful for the planning board to have the authority to require additional information on groundwater resources, and to require appropriate mitigation measures.

b. Recommendations. The subdivision regulations should be amended to include the following optional provisions, which may be applied at the discretion of the Planning Board where appropriate:

o Section 3.B.2.b, Existing Site Features

3) The Board may require that the following be submitted where such information is necessary to evaluate the plan because of special circumstances of the proposal or its location including, but not limited to, proximity to aquifers, groundwater recharge areas, or water supply wells:

aa) location of aquifers or recharge areas for existing or potential drinking water supplies.

bb) Maximum groundwater table elevation and direction of groundwater flow.

o Section 3.B.2.c. Engineering

11) The Board may require that the following be submitted where such information is necessary because of special circumstances of the proposal or its location including, but not limited to, proximity to aquifers, groundwater recharge areas, or water supply wells:

aa) Analysis of open and closed drainage system alternatives, examining effects upon the recharge of aquifers and the quality of the groundwater.

o Section 5.F Required Improvements, Storm Drainage

The Board may require that the following measures be taken because of special circumstances of the proposal or its location including, but not limited to, proximity to aquifers, groundwater recharge areas, or public water supply wells:

(1) Design and construction shall reduce, to the extent possible the following:

o dimensions of paved areas

o encroachment within any wetland or floodplain

o volume of cut and fill

o area over which vegetation will be disturbed

o extent of waterways altered or relocated

(2) Pollution control devices, including provisions for contaminant removal employing detention basins with subsurface drains or perforated risers, oil and grit separator catch basins, and other appropriate devices.

SITE PLAN REVIEW

a. Decription. Site plans are required for non-residential uses which are not subject to the subdivision regulations. In Carlisle, business uses are subject to site plan review. The Board of Selectmen reviews site plans submitted. The site plan provisions include a requirement that the Board of Selectmen, in considering a site plan, assure the "adequacy of the methods on the site for sewage, refuse, and other waste disposal, and for surface and subsurface drainage." However, groundwater protection is not one of the criteria for approval.

b. Recommendations. The site plan review section of the zoning bylaw should be amended by adding groundwater protection as a criteria for approval. Section 7.F should be amended to include the following new subsection:

g. Adequacy of the measures to prevent pollution of groundwaters or changes in groundwater level.

FOOTNOTES

1 Taylor, Floyd B., and Ryan, Christopher R., The Carlisle, Massachusetts Salt in Water Supply Problem, U.S. Enviromental Protection Agency, Boston, MA.

2 Cleverdon, Varney, and Pike, Inc., letter reports to the Town of Carlisle, January 19, 1979, and April, 1981.

3 Interdisciplinary Environmental Planners, Inc. (IEP), Environmental Impact Study, Conant Land, December 1977.

4 Caldwell, D.W., and Arora, Chauth Ram, Geologic and Hydrologic Maps for Land Use Planning in Carlisle, MA, 1973.

5 IEP Inc., op. cit.

6 Julio Olympio, U.S. Geological Survey, Boston, MA., Personal communication, January 9, 1984.

7 Cleverdon, Varney and Pike, Inc., op. cit., January 19, 1979.

8 Cleverdon, Varney, and Pike, Inc., op. cit., April 29, 1981

APPENDIX A

MODEL UNDERGROUND FUEL STORAGE BYLAW

Section 1: Authority

This bylaw/ordinance is adopted by under its home rule powers, its police powers to protect the public health and welfare, and its authorization under Massachusetts General Laws Chapter 40, section 21.

Section 2: Purpose

The purpose of this bylaw/ordinance is to control the installation and maintenance of underground gasoline or fuel storage tanks over 1000 gallons, and to protect groundwater and surface water from contamination due to leakage. The provisions of this bylaw/ordinance are applicable only to underground tanks.

Section 3: Definitions

3.1 - Underground tank shall mean any fuel-storage containment system for gasoline, fuel or lubricating oil with a capacity in excess of 1000 gallons, the top of which is located below the ground.

3.2 - Fire chief shall mean the chief of the fire department for the municipality in which a tank is located.

3.3 - Noncorrosive soil is soil that, when tested by a qualified professional, is shown to have a resistivity greater than 10,000 ohm-cm, and that does not exhibit corrosive characteristics in a soil-chemistry analysis.

3.4 - 100-year floodplain shall mean those areas as shown in the Flood Insurance Rate Maps for (community name) under the Federal Emergency Management Agency's National Flood Insurance Program, or as defined in section of the zoning bylaw/ordinance.

Section 4: Registration of Existing Tanks

**Note: This section is only needed for those communities that have not licensed tanks as required by M.G.L. Ch. 148, s. 13, or whose records are not up-to-date or are incomplete.

4.1 - Tank Registration

Every operator of an underground tank must file with the town/city clerk the size, type, age, contents, and location of their underground tanks within 90 days of the enactment of this bylaw/ordinance.

4.2 - Notification of Fire Department

The town/city clerk must forthwith, give the fire chief a copy of the information filed for each tank that is registered according to section 4.1. The fire chief or his designee must check this information against fire department records. He may require evidence of the date of purchase and installation if there is any question concerning the age of the tank.

4.3 - Tank Testing

Operators that are known to have underground fuel storage tanks that did not report their tank(s) as required by section 4.1 of this bylaw/ordinance must have such tanks tested in accordance with section 6.6 of this bylaw/ordinance.

Section 5: Standards Applicable to the Installation of New Tanks

5.1 - Tank Design

(a) Unless proven otherwise by soil tests performed by qualified professionals, the soils in Massachusetts shall be assumed to be corrosive. Metallic tanks (except stainless steel) without cathodic protection or an underground secondary-containment system will be prohibited. Also prohibited is schedule 40 steel pipe, galvanized or black iron, or approved nonmetallic (except fiberglass-reinforced plastic) pipe. If a qualified professional demonstrates that the soils in which the tank is to be placed are non-corrosive as described in section 3.3 of the definitions, a steel tank with interior coating and other approved piping may be installed.

(b) In corrosive soils, underground tanks must be constructed of: non-corrodible materials, such as fiberglass-reinforced plastic (FRP) or its equivalent; steel with external bonded non-corrodible material (i.e., FRP); a steel system cathodically protected by an impressed current cathodic system, sacrificial anodes, or equivalent protection; or, a double-walled tank. These requirements are in accordance with the Massachusetts Board of Fire Prevention regulations codified in 527 CMR 9.06 (18).

(c) In corrosive soils, piping shall be constructed of non-corrodable materials such as FRP or its equivalent, a steel system with cathodic protection, or some other type of equivalent protection, in accordance with 527 CMR 9.06 (18).

(d) Cathodic protection systems shall be maintained and checked in accordance with 527 CMR 9.06 (20) (g).

(e) Commercial tanks must be equipped with striker plates below openings used for product measurement or filling.

5.2 - Tank Installation

(a) The fire chief or his designee must inspect and approve underground tanks prior to their burial, in accordance with 527 CMR 9.06 (10).

(b) Tanks must be installed in accordance with the manufacturer's installation techniques. Damage to protective coatings or to the FRP tank or surface must be repaired prior to covering the tank.

(c) New underground tanks shall be tested for tightness, hydrostatically, or with air pressure at not less than 3 pounds per square inch and not more than 5 pounds per square inch, after installation, but before being covered or placed in use in accordance with 527 CMR 9.06 (20) (b).

(d) Piping should be tested in accordance with 527 CMR 9.06 (20) (a) before being covered, enclosed, or placed in use.

(e) Backfill material, used to cover all new tank installations and repairs, must be of the type and quality specified by the tank manufacturer's installation procedures, and by the pertinent regulations governing storage tank installation.

(f) Underground tanks that are to be located in areas subject to flooding or below the maximum water table elevation must be anchored according to manufacturer's instructions.

5.3 - Tank Location

(a) Underground tanks may not be installed within the 100-year floodplain.

(b) Underground tanks that are to be installed within the watershed of a drinking-water reservoir, or within the cone of depression of a public well (or lacking a defined cone of depression, within 1000 feet of a public water supply well), must submit, for review by the fire chief, the board of health or its agent, and the local water commissioners or their agent, a plan outlining the procedures or devices, such as product sensors and/or

5.3 - Tank Location (continued)

area monitoring devices, to be used to prevent water supply contamination. The plan must be endorsed by representatives of the three departments noted above prior to tank installation.

Section 6: Leak Detection for Existing and New Tanks

6.1 - Inventory Verification

(a) All underground tanks, except fuel-oil tanks and tanks connected with burning equipment, must be monitored for the prevention and detection of leakage of flammable and combustible liquids in accordance with the provisions of 527 CMR 5.05 (3).

(b) The daily-inventory records must be shown to the fire chief, or his designee, prior to issuance of a permit or license renewal.

(c) The owner and operator must participate in a program of regularly scheduled inventory verification, at least once every two years, in accordance with 527 CMR 5.05 (3) (g). The operator of tanks 10 years of age or older shall submit to the fire chief annually a report certifying that the inventory verification has been performed, stating the calculated gain/loss over the verification periods.

(d) The fire chief shall require the operator of an underground tank storage system to test the system for tightness, at the operator's expense, when accurate daily inventory records have not been maintained as specified in 6.1.

(e) If daily inventory records indicate a loss of product in excess of 0.5 percent of the volume of product used or sold, or an abnormal increase in the amount of water contained in the tank, steps must be taken immediately in accordance with 527 CMR 5.05 (3) (e) to detect and stop the leak. The discrepancy must be reported to the fire chief.

6.2 - Tank Testing

(a) Unless the tank operator demonstrates to the fire chief and the board of health that his tank(s) are constructed of a material that will not corrode, has product sensors, or has been repaired or tested within the last year, underground tanks shall be required, at the expense of the owner, to undergo one of the following tests at

6.2 - Tank Testing (continued)

five-year intervals from the date of installation, up to the twentieth year, and annually thereafter: A Kent-Moore (Heath Petro-tite) test; or a Sun-Mark leak-locator test; or the equivalent as determined by the fire chief. The fire chief shall be given at least 48 hours' notice of time, date, and place of testing. Test results must be submitted to the local fire chief.

(b) The waiver from 6.2 (a) may not be granted for a tank that is located within any of the areas specified in section 5.3 (b).

(c) If flammable fluids or their vapors have been detected in neighboring structures, sewers, or wells on or off the property locations, the fire chief may require that any nearby tank, including underground residential tanks less than 1000 gallons, be tested at the expense of each tank's owner.

Section 7: Procedure in Case of Spill or Leak

7.1 - Leak Reporting

Any person who is aware of a spill or abnormal loss of flammable fluids must report such spill or loss immediately to the fire chief. The fire chief must be responsible for other notification, including the board of health.

7.2 - Equipment Replacement/Removal

(a) After a leak is confirmed, underground tanks (or piping) must be emptied immediately, and removed or repaired forthwith, under the direction of the fire chief.

(b) A leaking tank that is twenty years old or older that does not comply with the design standards in section 5.1 (b) must be removed and may not be repaired. A permit for its removal must be obtained in accordance with M.G.L. Ch. 48, s. 38A.

(c) A leaking tank that is less than twenty years old must be repaired or removed. If the tank operator can show to the satisfaction of the fire chief that (in the case of steel tanks) the leak was from internal corrosion, and that the tank can be repaired so as not to pose a continuing threat to the soils and waters of the Commonwealth, considering at a minimum the corrosivity of

7.2 - Equipment Replacement/Removal (continued)

the soil; tank age and external condition; techniques to be used for the repair; and the location of the tank, then the tank may be repaired. Operators of leaking FRP tanks must demonstrate to the fire chief that the tank can be repaired according to manufacturer's instructions. Operators who do not meet these requirements must remove the tank.

(d) If it is necessary to replace an underground steel tank that has developed a corrosion-induced leak, all other steel tanks at the facility of the same age or older, whether they are leaking or not, shall be repaired or replaced with tanks that meet the requirements of Section 5.1 of this bylaw.

Section 8: Administration

8.1 - The provisions of this bylaw shall be administered by the fire chief.

8.2 - Variances from the specific requirements of this bylaw/ordinance may be authorized by the chief licensing authority after notice and a public hearing.

8.3 - Licenses issued in accordance with M.G.L. Ch. 148 s. 13 for underground tanks must be renewed at five-year intervals from the date of installation, up to the twentieth year, and annually thereafter. Tank owners must submit to the fire chief and the licensing authority a statement certifying satisfactory leak-detection results over the period of the permit (in accordance with s. 6.2 of this bylaw), and inventory verification, at least 30 days before the issuance of a permit renewal for the time periods specified herein. Test results must accompany the permit renewal application.

8.4 - Fees necessary for the issuance and renewal of permits or licenses shall be set by the board of selectmen.

8.5 - The fire chief or his designee may, at all reasonable time and upon reasonable notice to the occupant of the premises enter any premises, public or private, for the purpose of investigating, sampling, or inspecting any record, condition, equipment, practice, or property relating to activities subject to this bylaw/ordinance, and may at any time and upon reasonable notice to the occupant of the premises enter such premises for the purpose of protecting the public health or safety, or to prevent damage to the environment.

APPENDIX B

SEPTIC SYSTEM INSPECTION AND MAINTENANCE PROGRAMS

Septic system maintenance makes economic as well as environmental sense. It is an inexpensive and environmentally-sound alternative to septic system repair or expansion of public sewer systems. A septic system maintenance program is a preventative approach to problems that might result from malfunctions. The primary goal is to periodically have systems pumped to provent sludge overflow and clogging of the leaching area.

There are two major components to an effective septic system inspection and maintenance program. The first is public education. The second is monitoring and enforcement by the town.

VOLUNTARY I & M PROGRAM

There are many ways to encourage local residents to maintain their system on a voluntary basis. The prerequisite to such a voluntary program is public education.

Public-Education Program

A public-education program could be carried out in a number of ways. Some ideas are presented below.

1. Distribution of Septic System Brochure. A septic-system maintenance brochure could be distributed by the board of health or other town officials. If the brochure is brief, perhaps it can be mailed to homeowners along with the water bill, tax bill, or town-meeting warrant. This way, the brochure could serve as an annual reminder that septic systems should be checked to avoid unnecessary expenses. The brochure could be distributed to new residents by the "Welcome Wagon," real-estate agents, or bank mortgage officers. Finally, septic system installers and licensed pumpers, who deal with homeowners when they should be most receptive to hearing more about maintaining their system, can be asked to distribute the brochure.

2. Press Releases. The board of health or conservation commission could periodically submit press releases to local newspapers as a way of informing townspeople about septic systems and the importance of maintaining them. The newspaper articles should also contain the Board of Health's telephone number, where further information can be obtained.

3. Local Schools. Septic-system maintenance brochures can be handed out to school children as part of a natural resources program (perhaps within the science department). The children, as part of their assignment, could be asked to go home and find out what their parents know about their system and could, in turn, show them the brochure.

4. Encourage Involvement from Septage Haulers. A meeting could be arranged between town officials and local private septage pumping/hauling companies to explore methods for encouraging homeowners to regularly inspect and service their septic tanks. Some of the options for discussion are listed below.

   Septage haulers could be encouraged to increase their advertising, particularly with respect to informing homeowners about protecting their investment in the septic system by regular maintenance. Some septage haulers send customers a reminder every few years that their system is due for a pumping. Septage haulers and neighbors could negotiate a long-term agreement and schedule for pumping service. Some septage haulers will provide service at a reduced cost for each participating household since this approach reduces time and travel expenses for the hauler. Septage haulers could be encouraged to permit homeowners to charge maintenance and pump-out services on Master Card or Visa.

5. Public Meetings/Workshops. Assistance can be obtained from the U.S. Soil Conservation Service, Agricultural Extension Service, or regional planning agency to present a slide show and talk on septic system maintenance. If the meeting is widely publicized, perhaps following a brochure mailing, local school program, or press release, attendance can be enhanced.

Monitoring

A voluntary septic system inspection and maintenance program is difficult to monitor and enforce. Three monitoring options are presented below.

1. The board of health could perform random spot-checks around the town to get a general idea of the program's success.

2. The board of health could, along with a septic-system brochure, send a notice to all septic system owners, notifying them that their systems should be inspected, with a mail-back response postcard attached. The board of health would maintain a file of returned pumping-notice forms as a way of monitoring the number and frequency of septic system pumpouts.

3. All licensed pumpers in the town could be required to submit to the board of health a copy of all receipts, signed by homeowners, whose systems have been pumped. This type of monitoring system would require adoption of a health regulation or town bylaw, and would, therefore, be more appropriate as part of a mandatory inspection and maintenance program.